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COMMENTS ON ADVANCE COPY OF SUMMARY REPORT ON MERAMEC RIVER, MI--ETC(U)

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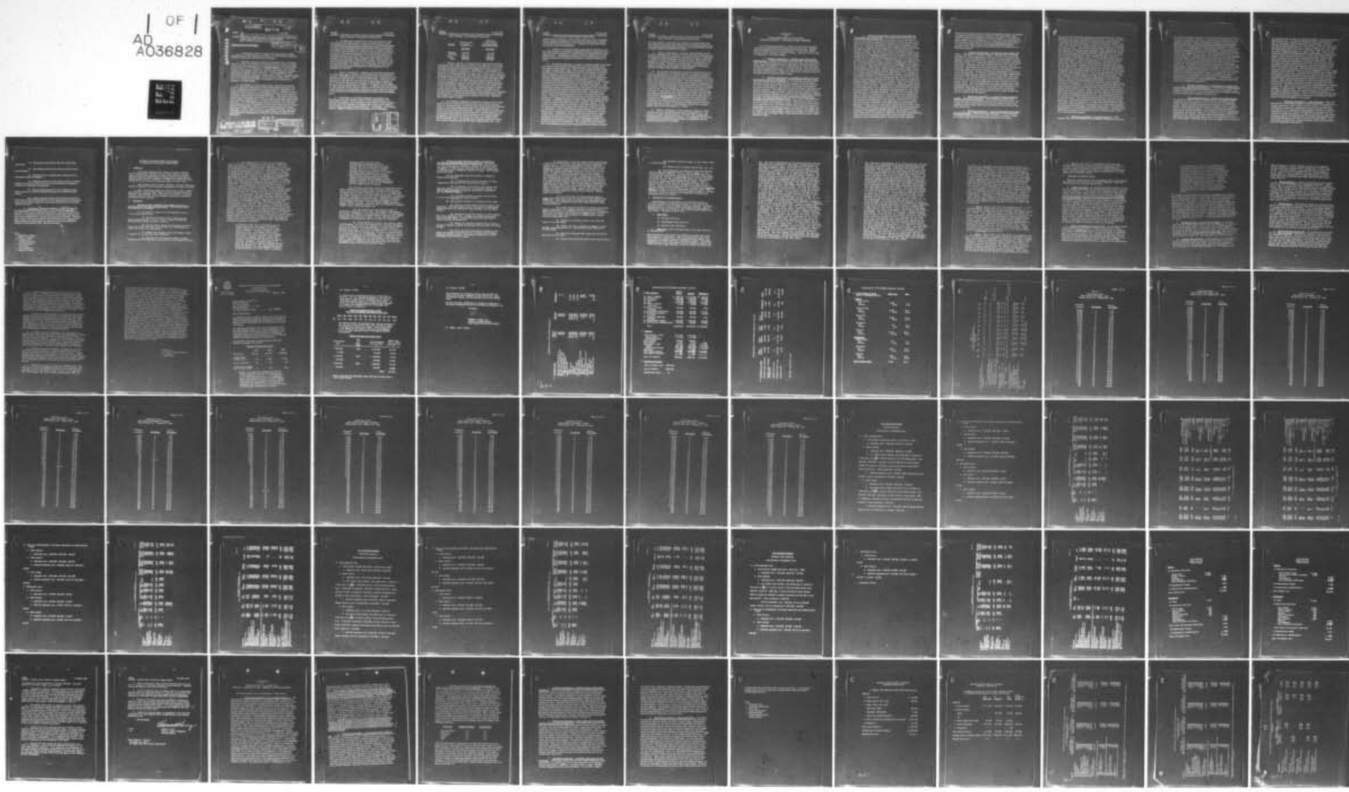

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U.S. Army Engineer District, St. Louis, Mo.
~~Corps of Engineers~~
~~St. Louis~~, Missouri

401538

ENGBR

23 July 1965

SUBJECT: Comments on Advance Copy of Summary Report on Meramec River, Missouri, Comprehensive Basin Study,

MEMORANDUM FOR RECORD:

23 Jul 65

79p.

1. A preliminary review of subject report has raised a number of questions on which additional information or clarification is required. These are discussed in the following paragraphs.

2. Reference is made to letter of 24 November 1964, on subject report, in which it is stated that "The Board decided to return the report to the District to await receipt of the official report of the Public Health Service from the U. S. Department of Health, Education, and Welfare, relating to the potential needs and value of water storage for municipal, industrial and quality control purposes." A report prepared by HEW Public Health Service, Region VI, Kansas City, Missouri, December 1964, has been included as Attachment 1 on the subject summary report. However, it is understood that HEW, Washington, has not yet given its approval to the field report.

3. Attachment 2, on the summary report, presents a derivation of water supply and water quality control requirements prepared by the Corps of Engineers and stated to be based on data and information furnished informally by the U. S. Public Health Service. However the water supply and water quality demands developed by the Corps are somewhat larger than values shown in the HEW field report. Both reports state that the only area in the basin where there is a need for low-flow augmentation in the interest of water supply, is in the lower Meramec River basin area-Reach M-7. The HEW report states that the withdrawal of ground water in the upper areas may be increased to 280 million gallons per day without depletion of the aquifer. Since the need for water quality in the upper basin prior to 2020 is about 70 m.g.d., as indicated by HEW, consideration might be given to the use of this ground water as the need develops, as an alternative supplementary source for water quality control in the upper basin.

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4. The HEW report, page VIII-13, states that the most likely alternative to providing reservoir storage for water quality control above Reach M-7, was found to be pumping part of the treated wastes 19 miles to the Mississippi River where sufficient flow is available to satisfactorily assimilate the treated wastes. The annual value of 342,000 acre feet of demand on storage for quality control regulation is given as the annual transmission cost of the treated waste to the Mississippi River which is $261,000. The Corps report allocates a maximum of 191,000 acre-feet of storage for water quality control in the three large reservoirs, Meramec Park, Union, and Pine Ford, for which the allocated total annual cost is $356,200. See Tables 5 and 14 of summary report. It appears that the alternative is less costly and water quality storage as proposed for these reservoirs is not economically justified.

5. Table 7, attachment 2, indicates that the storage deficiency for water supply only,--based on the assumption that the treated M-7 wastes are pumped 19 miles to the Mississippi River,--would be 167,051 acre-feet for sub-basin M-7, to meet the 2070 needs. The Corps report provides for more than 430,000 acre-feet of water supply storage by 2070, because of the sharing of recharge or streamflow with the needs for water quality control reservoir storage. It appears that the difference in costs between the 167,000 acre-feet and the 430,000 acre-feet of water supply storage plus corresponding evaporation losses might be credited to the alternative of pumping the treated M-7 wastes to the Mississippi River.

6. On the basis of the above paragraph on pumping to the Mississippi River the reservoir storage of 332,000 acre feet in the Meramec Park project, now allocated to water supply and water quality, would be more than adequate to serve the entire water supply needs in the M-7 basin area until after the year 2070. Accordingly, on this basis reservoir storage reduction would be practical for the following:

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Project	Storage given in report	Estimated storage needed as revised above
	acre-feet	acre-feet
Irondale	161,000	44,500
Pine Ford	285,000	220,000
Union	528,000	383,000
Total	974,000	647,500

7. Table 5, page 24, of summary report shows that the storage allocated to local water quality control for I-38 reservoir is 2,500 acre feet and the corresponding allocated average annual cost is $132,900. The HEW field report, on Exhibit 12, attachment 1, gives benefits for water quality control in reaches B-1, B-2, and B-3 as $73,600 annually based on 14,900 acre feet draft on storage from a single purpose reservoir developed at the I-38 reservoir site. The Corps project indicates storage for quality water control developed at a first cost of $2,643,000/2,500 or $1,060 per acre-foot, and HEW indicates storage for water quality control developed at a cost of $4,200,000/14,900 or $280 per acre-foot, which discounted at 3 percent from 1990 to 1970 is $2,326,000/14,900 or $156 per acre-foot. It appears that the alternative project for water quality control is less costly than when storage is included in I-38, and therefore water quality storage should not be included in this multiple-purpose project. A project for flood control and recreation only at this site appears to be not economically feasible at this time. Additional data in this regard is needed.

8. As indicated in paragraph 6 above the capacity of the Irondale project should be reduced from 161,000 acre feet to 44,500 acre feet. Since the conservation and recreational water surface areas would become smaller by the revised formulated project the recreational costs and benefits should be adjusted accordingly. Based on maximum surface area of the conservation pool, the revised recreation benefits apparently will become about one-quarter the value proposed for the original project. Furthermore under PL 89-72, dated 9 July 1965, the "Federal Water Project Recreation Act," the average annual charges allocated to recreation should not exceed one-half the total average annual cost. The

Irondale project proposed in the summary report has a ratio of average annual charges for recreation to total project average annual charges of $426,900/$670,200 or about 0.64. Therefore on this basis alone, the project should be reformulated.

9. Reduction in reservoir storage capacities for both Union and Pine Ford projects as discussed in paragraph 6 above, apparently would result in costs for recreation in conflict with the Federal Water Project Recreation Act. Consideration should be given to modification of the storage capacities and appropriate changes in recreation features and costs.

10. The District Engineer, on page 54, paragraph 39d(1) recommends non-Federal interests give assurances that they will repay the costs allocated to water supply, etc. Costs of water supply storage to meet the needs over the first 50 years of the period of analysis are presently estimated at $761,000 for construction and $3,700 annually for maintenance, operation, and major replacements. Costs of water supply to meet the needs covering the last 50 years of the period of analysis are currently estimated at $8,283,000 for construction, etc. It might be understood from this statement that for the water needed the last 50 years, there should be no charge for interest on the preceding 50 years. See paragraphs 29 and 36 of summary report. However, assuming a 10 year interest free period on future water supply the interest on the $8,283,000 compounded over the interim 40-year period alone would amount to 242 percent of the basic amount or roughly $20 million. Therefore future water supply 50 years hence should cost local interests at least $28 million. However, if the future water supply is omitted from the project formulation a comparable amount of water quality storage should likewise be omitted. The Water Supply Act of 1958, provides that modification of a reservoir project heretofore authorized, surveyed, planned, or constructed to include storage as provided, which would seriously affect the purposes for which the project was authorized, surveyed, planned, or constructed, or which would involve major structural or operational changes shall be made only upon the approval of Congress as now provided by law. Furthermore, if water supply and water quality control storage for the second 50-year period is not included in the project formulation and the storage capacity is not changed, the storage corresponding to the future use for the above two purposes should be allocated to specific use for recreation. This storage would then become part of the separable costs to recreation and the costs should be shared

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by local interests. After the local interests have contracted to pay their share for recreation there appears to be a question whether they would later allow the storage for recreation to be converted to storage for water supply and water quality control.

11. Table 8, attachment 5, provides a cost allocation for #17 Meramec Park Reservoir. However it is not possible to determine how the reservoir storage allocation and conversion on Table 7, attachment 5, affects the costs and benefits for water supply, water quality and recreation, as shown in Table 8, for each 25-year period as the conversions are made. Copies of cost allocations, corresponding to Table 8, should also be furnished for the information of the Boards staff for the other 4 major reservoirs recommended.

12. On the basis of allocation of costs for reservoirs shown on Table 9, attachment 5, the cost per acre-foot of storage allocated to water quality varies from $1,060 for I-38, to about $37 for Meramec Park,--and the cost per acre-foot allocated to water supply varies from $43 for Pine Ford to $1.50 for Irondale. The wide difference in cost between water quality storage and water supply storage is apparently due to the values based on the least costly alternative from which benefits are derived, and the discounting of values from the time that the needs should be met. In this connection attention is invited to Exhibit 13, attachment 1, HEW report. By programming construction for a sewage plant effluent pumping system in stages in 1990, 2020, and 2050, the construction cost was discounted from $26,300,000 for first cost of construction to ~~$1[illegible],000~~ $6,725,000 for construction as the need develops. It is apparent that delaying construction of certain reservoirs on an equivalent basis to serve the water quality needs and also the water supply needs would result in more favorable benefits and a greater benefit-cost ratio for the system as a whole.

13. Table 2, attachment 5, cost estimates, angler-use sites, indicates that all lands and damages will be at Federal cost. This appears to conflict with ER 1165-2-4, 12 January 1965, Recreational Developments at non-Reservoir Projects. It is suggested that the cost estimates for the angler-use sites be made in accordance with the ER, and data furnished for the Board.

COMMENTS
ON
BERH MEMORANDUM FOR RECORD
(SUMMARY REPORT - MERAMEC RIVER, MISSOURI)

The following information is furnished on views and comments contained in Memorandum for Record inclosed with letter, ENGBR, Board of Engineers for Rivers and Harbors, 27 July 1965, subject: Meramec River, Missouri, Summary Report. References below refer to paragraphs in the Memorandum.

a. Reference paragraph 2 - official report of the Public Health Service. Report of the Public Health Service, dated December 1964, was officially approved by the Chairman of the Review Board for Water Supply and Pollution Control, Department of Health, Education, and Welfare, Washington, D. C., in February 1965. This was reconfirmed in telephone conversation on 28 July 1965 with representative of the Public Health Service, Region VI, Kansas City, Missouri, who was charged with the preparation of the report.

b. Reference paragraph 3 - derivation of water supply and water quality control requirements. In the derivation of water supply and water quality control requirements, the District used seasonal demands for both water supply and water quality control furnished by the Public Health Service. The difference in storage requirements determined by the Public Health Service and the Corps is reflected in the method of analysis. The Rainwater method used by the Public Health Service indicates draft-on-storage, which is the sum of the incremental excesses of needed releases over inflow during a climatic year, whereas the Corps analysis indicates storage requirements needed to meet demands over critical periods of record. For a fuller understanding of the Public Health Service analysis, there is attached as inclosure 1 a copy of critique on the Rainwater method. With regard to water quality in the upper basin area, the Public Health Service considered the use of groundwater as an alternative source, but found that the capital cost of the wells, which would require aerators and pumps, was higher than the capital cost of single-purpose reservoirs to supply the needed quality control water (see page VIII-9, Public Health Service report, dated December 1964).

c. Reference paragraph 4 - least costly alternative for water quality above Reach M-7. The annual value of $261,000 estimated by the Public Health Service was based on the summation of costs for incremental pumping requirements to handle the waste loadings which exceed the assimilative capacity of the unregulated stream flows, Q_i. Pumping requirements reflect monthly variations in the assimilative capacity of the unregulated stream flow that theoretically would be exceeded 95 percent of the time, as determined by the Rainwater method. The value for Q_i used by the Public Health Service exceeds the corresponding unregulated flow as computed by the Corps of Engineers on a statistical basis by 40 to 58 percent for the summer season, 34 to 76 percent for the spring season, and an average of 35 percent for the winter season. From the foregoing, it is apparent that the use of the Rainwater method credits the unregulated stream flow, Q_i, in excess of the actual flows for the corresponding percent chance of occurrence. Reference is made to Table No. VIII-5, page VIII-13, Public Health Service report, which indicates that the summer season is critical in determining the benefits applicable to water quality control, whether based on dilution or pumping of waste. A reanalysis of the benefit evaluation was undertaken by the District based on the critical summer season. Since the unregulated flow, Q_i, for the summer season is approximately 50 percent too high, the amount of waste to be pumped would essentially have to be doubled. Basic cost data used by the Public Health Service in its evaluation are contained in letter dated 5 August 1965, inclosure 2. Pipeline costs, including applicable material and installation, were estimated to account for about 75 percent of the construction costs, the remaining 25 percent being the cost of the pumping station, including equipment. To handle the increased waste load, it would be necessary to increase the pipe size and double the capacity of the pump installations. Pipeline costs were increased 50 percent and the pumping station 100 percent. Assuming 80 percent of the operation and maintenance costs applicable to the cost of energy and 20 percent for materials in the pump station and maintenance of pipelines, energy costs were increased 100 percent and all other costs 20 percent. Based on the 3-1/8 percent interest rate and amortization over 100 years, discounted benefits applicable to the alternative of pumping are estimated at $377,000 annually. This analysis is based on the same years of first need as indicated by the Public Health Service, which is in error since with lesser flow, time-of-needs would be advanced and the discounting effects would be less than indicated.

Based on the Corps procedures used in the Summary Report, the amount of pumping required during the critical low-flow periods of record would be greater than indicated in the above analysis. From the foregoing analysis, it is concluded that: (a) the least costly alternative for water quality control above Reach M-7 is single-purpose reservoirs, as used by the Corps, and (b) water quality storage provided in Meramec Park, Union, and Pine Ford Reservoirs is needed and economically justified.

d. Reference paragraph 5 - storage for water supply only. Table 7, Attachment 2, Summary Report, indicates that the storage deficiency for water supply alone would be 167,051 acre-feet for subbasin M-7 to meet the 2070 needs. In order to avoid complete stream depletion, these requirements were analyzed over and above a selected base flow of 195 c.f.s., being the minimum flow of record in the lower basin area. Deficiency for water quality alone amounts to 393,725 acre-feet. When based on concurrent demands, the total deficiency for both water supply and quality control by the year 2070 becomes 1,180,568 acre-feet. The five reservoirs recommended for construction in the basin plan are capable of meeting all the water supply needs to the year 2070 and water quality needs to the year 2045 in the lower basin area. The adjusted amount of storage required is estimated at 430,092 acre-feet for water supply and 190,461 acre-feet for water quality control. All the foregoing figures exclude allowance for evaporation losses. Since the alternative of pumping treated wastes to the Mississippi River was found not to be the least costly alternative, as indicated in subparagraph c above, the difference in cost between 167,051 acre-feet and 430,092 acre-feet of water supply storage cannot be credited to this alternative.

e. Reference paragraph 6 - reservoir storage reduction, Irondale, Pine Ford, and Union. Since pumping of wastes to the Mississippi River was found not to be the least costly alternative, the storage provided in these three reservoirs is needed to serve water supply and water quality demands to the fullest extent practical in the lower basin area.

f. Reference paragraph 7 - cost of storage for water quality I-38 Reservoir. Draft-on-storage estimated at 14,900 acre-feet is based on reservoir releases for the year 2070, as shown in Table No. VIII-4, page VIII-12, of the Public Health Service report.

Storage of 2,500 acre-feet estimated by the Corps represents supplemental storage required during the first 50 years, or to the year 2020. To compare this figure with Public Health Service values, monthly releases for the year 2020 needs, as shown in Table No. VIII-4, were used. The total draft-on-storage based on these releases is estimated at 2,340 acre-feet. The size of a single-purpose reservoir to provide this draft-on-storage must include allowances for evaporation, as well as sedimentation. Using Corps estimates, approximately 1,855 acre-feet of storage would be required for evaporation and 4,715 acre-feet for 100-year sedimentation. Thus, the total storage required in a single-purpose reservoir amounts to 8,910 acre-feet to meet the year 2020 requirements. Table 2 of Attachment 4 to the Summary Report shows that 9,042 acre-feet of storage, having a reservoir cost of $4,055,000, would be required for Reaches B-1 through B-3 to meet the year 2020 needs. Assuming a reservoir to meet the Public Health Service draft-on-storage of 2,340 acre-feet for the year 2020 to have a comparable cost of about $4,000,000, the unit cost per acre-foot would be equal to approximately $1,710. The Corps allocated unit cost for water quality of $1,060 reflects a savings in project joint costs. Further reference is made to Table 5 of Attachment 2 to the Summary Report. Base storage requirements amounting to 17,215 acre-feet would be needed to meet the 2070 needs at Sullivan, which includes Reaches B-1 through B-3. To this are added evaporation requirements of 2,168 acre-feet and 4,715 acre-feet of storage for sedimentation. A single-purpose reservoir to meet the 2070 needs would require a total capacity of 24,098 acre-feet. Table 2 of Attachment 4 to the Summary Report shows that a reservoir having a storage capacity of 24,098 acre-feet would cost approximately $4,705,000. The unit cost for the effective storage is estimated at $273 per acre-foot ($4,705,000 divided by 17,215 acre-feet). This compares with the $280 per acre-foot cited by the Board. Attention is also invited to the fact that the annual charge of $73,600, shown in Exhibit No. 12 of the Public Health Service report, is based on construction costs only and does not reflect annual charges for operation and maintenance, including replacements. From the foregoing analysis, it is concluded that project formulation, cost allocations, and benefit evaluations for Reservoir I-38 are correct and the reservoir is economically feasible.

g. Reference paragraph 8 - Irondale Reservoir. Since Irondale Reservoir as formulated in the Summary Report does not meet

the criterion outlined in Section 9 of the Federal Water Project Recreation Act, approved 9 July 1965, in that the sum of allocations to recreation and fish and wildlife enhancement exceeds the sum of allocations to other uses, a review of project formulation was undertaken. This reservoir was given a high priority by the Bureau of Outdoor Recreation. In reformulation, consideration was given to providing as large a normal water surface area as practical. The total joint-use storage was reduced by 21,000 acre-feet and the normal pool area 500 acres, from 4,600 to 4,100 acres. The top elevation of the dam was lowered three feet. The total cost of the project is currently estimated at $12,900,000. Of the total reduction in first cost of $1,500,000, $137,000 is in the cost of recreation facilities based on a lesser water surface area and recreational lands and a reduction in visitor-day attendance. The project as reformulated would retain the benefits for flood control, water quality control, and navigation, whereas the water supply and recreation benefits would be reduced. The benefit-cost ratio for the project is estimated at 1.3 to 1.0 and meets the criterion of Section 9 of the Federal Water Project Recreation Act, having a ratio of first costs allocated to recreation and fish and wildlife enhancement to total project costs of 0.45 to 1. Pertinent data on the project as reformulated, including allocated costs and cost apportionment, are contained in inclosure 3.

h. Reference paragraph 9 - modification of storage capacities in Union and Pine Ford Reservoirs. As indicated in subparagraphs c and e, no storage reduction in these reservoirs is warranted. Furthermore, both projects as now formulated meet the criterion of Section 9 of the Federal Water Project Recreation Act.

i. Reference paragraph 10 - future water supply storage. The Summary Report, Table 16, shows costs to be repaid for water supply storage to be utilized in the first 50 years and the additional cost for storage to meet long-term needs during the second 50-year period. These estimates are based on the schedule of use as given in Table 5 of the Summary Report. Contractual agreements would be required for storage allocated to water supply to meet the demands for the first 50-year period. However, only assurances are required that demands for use of future storage would be made within a period of time which will permit paying out the costs allocated thereto within the life of the project. Since the storage for water supply to be used during ?

the second 50-year period is not dedicated initially, but converted from other interim uses, no interest charges should be required prior to time of conversion. Similar provisions are included in contracts between the United States and the City of Paris, Texas, for water storage space in Pat Mayse Reservoir, dated 14 January 1965, and between the United States and Trinity River Authority of Texas for water storage space in Bardwell Reservoir, dated 13 May 1963. Both of these contracts provide for reimbursement of costs allocated to initial water supply storage and only assurances for future water supply storage. Neither contract includes interest payment for future water supply prior to the time such storage is first used for that purpose. The Governor's Advisory Committee on Resurvey of the Meramec Basin expressed the opinion that provision for future water supply storage should be included in the comprehensive plan for development of the water resources of the basin. Enabling legislation enacted by the Legislature will permit the State to assume obligations for water supply storage in the reservoirs. To include provisions for water supply and water quality control requirements for the second 50-year period in the initial construction is more economical than it would be to fully or partially defer such provisions until the demand for such purposes arises. In the interim, this storage is used to the maximum extent practical for recreation, and local interests are paying a fair share for such use. In no case is the recreational reimbursement for specific storage, but rather a cash contribution for modifications to provide optimum recreation usage. There is no basis for storage ownership, but rather a sharing in costs in relation to applicable benefits, as reflected in project formulation. There is every reason to believe that the State accepts this premise and will sponsor and fulfill the requirements for local participation in recreation.

j. Reference paragraph 11 - cost allocations. Table 7 of Attachment 5 to the Summary Report reflects the phased supplemental storage required for water supply and water quality, as derived in Attachment 2; timing and supplemental storage requirements which were the bases for evaluation and discounting of benefits, as shown in Attachment 4; bases for benefits and applicable increments of costs used in the project formulation, as shown in Attachment 3; and blocks of storage used for determining dual cost aspects and applicable benefits for suballocations used in the reservoir cost allocations. Cost allocations for Pine Ford, Irondale (revised), Union, and I-38 Reservoirs are contained in inclosure 4.

k. <u>Reference paragraph 12 - costs per acre-foot of storage.</u> The wide difference in cost between water quality storage and water supply storage is due to the values based on the least costly alternative from which the benefits were derived and discounting effects in relation to the time of need. The value of both water supply and water quality in the lower basin area, Reach M-7, was based on a single-purpose reservoir (Meramec Park), whose unit construction cost per acre-foot of storage is by far the cheapest in the basin. The benefits for these needs were then prorated to the individual reservoirs in relation to the storage provided. Since in all cases benefits for water quality governed in the cost allocations, the unit cost allocated to water quality in Reach M-7 proved to be far less than the unit cost allocated for water quality in the upper basin. Allocations of costs to recreation reflect the fact that the "other" cost aspect of the separable cost varies from a low of $449 per surface acre for I-38 to $1,670 per acre for Pine Ford. Surface acre was used as the unit measure of value since it is one of the more important criteria for recreational planning. Reservoir I-38, whose total joint-use storage is used within the first 50 years, carries the least applicable unit cost per surface acre for the "other" costs. Delaying construction of any of the reservoirs recommended for authorization in the Summary Report to serve the water supply and quality demands as the need arises would not be responsive to the basin needs, the dominant of which are flood control and recreation; would not provide for an equitable distribution of beneficial effects from the developments, both in time and geographic area; would unquestionably result in substantial overall increased costs; and would be locally unacceptable.

l. <u>Reference paragraph 13 - cost estimates for angler-use sites.</u> Cost estimates for angler-use sites have been reviewed in accordance with ER 1165-2-4, dated 12 January 1965. Estimates have been revised to show the cost of lands as a non-Federal responsibility. The total cost of the recreational development now provides for equal distribution of costs between Federal and non-Federal interests, as shown in inclosure 5.

m. <u>Summary - general plan.</u> In project formulation for the basin plan, consideration was given to a number of factors, the more significant of which are stated below:

(1) Basin needs are based on 100-year projections, 1970-2070.

(2) The dominant needs in the basin are flood control and recreation.

(3) Reservoir sites to satisfy major segments of the widespread needs are limited.

(4) Additional capacity to meet future needs is included initially in reservoirs where such can be accomplished at significant savings over subsequent enlargement.

(5) Storage requirements for water supply and water quality control are based on demands furnished by the Public Health Service.

(6) Draft-on-storage and the value of such storage furnished by the Public Health Service are not representative of operational requirements needed to meet the concurrent demands over the critical periods of record.

n. Conclusion. Based on acceptance of ~~the~~ certain criteria cited in subparagraph m above, the general plan of basin development as proposed in the report is properly formulated, and will provide for the best use or combination of uses of water and related land resources to meet all foreseeable short- and long-term needs in the basin. Meramec Park, Union, Pine Ford, Irondale, and I-38 Reservoirs, proposed for authorization and construction, are required to meet the immediate demands in the Meramec River Basin at this time.

5 Incl
1. Rainwater critique
2. PHS ltr 5 Aug 65
3. Pertinent data - Irondale Reservoir
4. Cost allocations - reservoirs
5. Cost estimates - angler-use sites

not include

CRITIQUE OF RAINWATER METHOD FOR EVALUATION
OF WATER SUPPLY AND QUALITY CONTROL NEEDS

1. REFERENCES

a. Staff paper prepared by Mr. Frank H. Rainwater, Physical Science Administrator, Technical Science Branch, Division of Water Supply and Pollution, Department of Health, Education, and Welfare, entitled "Hydraulic Facts Needed for Studies of Flow Regulations for Stream Quality Control," presented at a symposium on stream flow regulation for quality control at Cincinnati, Ohio, 3-5 April 1963.

b. Paper prepared by Mr. Frank H. Rainwater, entitled "Hydrologic Aspects of Analysis of Flow Regulation Requirements for Quality Control."

c. Report submitted by Region VI, Public Health Service, Kansas City, Missouri, entitled "Water Resources Study, Meramec River Basin, Missouri," dated February 1964. This study, since revised, indicated potential needs and value of water storage for municipal, industrial, and quality control purposes.

2. BACKGROUND

a. Critique of paper "Hydraulic Facts Needed for Studies of Flow Regulations for Stream Quality Control." The following points were presented in the paper:

(1) The hydraulic analysis for flow regulations study is a four-step procedure which:

(a) Describes the present annual stream flow and quality characteristics in terms of typical companion hydrographs having selected average recurrence intervals.

(b) Projects future stream flow and quality characteristics that would exist under projected water use and management in year(s) "X" without flow regulations.

(c) Computes the regulated stream flow regimen needed in year(s) "X" to meet the quality objectives.

(d) Schedules the flow regulation needs, including probable monthly distributions, over the life of the proposed structure.

(2) The responsibility involved in a flow regulation study is to control stream quality, not to maintain a stream flow. Hence, maintenance of a constant minimum stream flow is not the most efficient answer to quality control. Maximum regulation demands do not necessarily coincide in time with either minimum stream flows or maximum concentrations of pollutants. For example, the process of counteracting a BOD load imposed on a stream involves the oxygen concentration of receiving water, the reaction rate (deoxygenation), and reaeration factors - each of these is temperature sensitive. Hence, the stream flow requirement is dependent partially on temperature. In mineral quality control, the tons of mineral to be diluted may be less at minimum flow, or maximum concentrations, than at some higher flow. As is evident from the nature of the problem, its solution is approached through a chain of dependent sequential analytical treatments of facts and figures. Probably the most significant deficiency (knowledge) lies in the realm of interrelating water quality and stream flow. Stream quality and stream discharge are inseparable in these studies. For the purposes of analysis, each event in the past and future time series of events comprising stream behavior has two dimensions - quantity of flow and concurrent quality. One objective of flow regulation for quality control is satisfactory concentration of waterborne material. Knowledge of stream flow characteristics is of little use unless it can be associated closely with attendant stream qualities. With respect to stream flow alone, information available on the low-flow characteristics is weak in both national coverage and validity. Low flows are extremely sensitive to effects of geology, land use, and man's modification of the hydrologic regimen. Interstation correlation and regional analysis, so useful in flood frequency analysis, are only of limited use in low-flow studies. Time-of-travel data and velocity profiles of low-flow conditions are needed to route pollution loads, to position oxygen sags along the stream, and to predict sludge deposition and scour. Such data are virtually non-existent nationwide.

(It should be noted that in conjunction with the Meramec Basin Study, two reports undertaken by separate agencies were available for use in this phase of analysis. One was an "open-file report" prepared by the U. S. Geological Survey, Water Resource Division, Rolla, Missouri, on the Meramec River Basin. This was a low-water study covering the period 24 September through 1 October 1953. Because of existing drought conditions and apparent low-water discharges, a low-water study of the basin was made involving numerous discharge measurements and observations. The study was made for the following purposes: to better determine the distribution of the base flow in the basin; to determine

the gain or loss of water between various points in the basin; to compare the flow during this drought with the previous low flows of record at the gaging stations; and to have on record a better coverage concerning the low flows in the basin. The second study, prepared by the Missouri Water Pollution Board in 1963-64 contained detailed data from sampling stations established to determine the utilization of water resources; biological data; and bacteriological, chemical, physical, as well as flow information for the streams within the basin.)

(3) Since flow regulation studies are recognized as forecasts, statistical treatments of data are useful tools in a time series, such as historic stream flows. The size of the sample may be equated with the number of years of the record. In theory then, the longer the period of record, the better the estimate. In practice, this is not necessarily true because man is changing the statistical population from which the sample is drawn. Regulation, diversion, and increased consumptive use are continually changing the water quality regimen of streams. The water quality regimen responds to changes in flow regulation and also to man's use of water to transport wastes. Factors affecting changes are:

(a) Data obsolescence, the effects of which are particularly pronounced in low flows. This problem of obsolescence has several consequences in flow regulation studies. The hydrologists may be seriously misled by published low-flow frequency data compiled, unadjusted, from the historic record. Usually, such data require considerable reworking before they can be used with confidence.

(b) Stream depletion is another very important aspect of obsolescence. To fulfill its responsibility in making recommendations to the Federal construction agencies, the Public Health Service must base its analysis of regulation needs on future depleted or modified stream flows. The flow to be augmented 20 or 50 years hence will not be the same flow measured now, but rather a stream depleted by the existing water use and management. What is needed are accurate projections of depletion and other modifications. Regardless of the nature of the consumptive user, 30 to 40 percent of the water withdrawn in the United States is lost from the supply. No stretch of the imagination is required to see that future depletions will make increasing inroads on the static available supply.

b. <u>Critique of paper "Hydrologic Aspects of Analysis of Flow Regulation Requirements for Quality Control."</u> This paper outlines the approach to approximate "present and projected needs for stream flow regulation (draft-on-storage) for quality control independent of other proposed, predicted, and as yet unestablished or authorized uses of stream and reservoir storage." The following points were made:

(1) Mr. Rainwater's analytical method is designed to answer three questions:

(a) To establish the need and the amount of water releases from the reservoir for stream quality control.

(b) To establish if the flow at the reservoir site (and load center) is equal or exceeds the necessary releases, or whether <u>draft-on-storage</u> (stream flow regulation) is required to meet the necessary releases.

(c) If draft-on-storage is needed, how much water is to be stored <u>each year</u> for quality control.

(2) The analytical procedure is divided into four steps:

(a) Describe the base system in terms of quality and stream flow. This base system reflects the effects of existing and authorized water uses, permissible waste loadings, and flow modifications.

(b) Superimpose projected increases in waste loadings, water uses, depletions, etc., to change the stream quality and/or flow of the base system. The projected systems are described in terms of quality and stream flow.

(c) Compute the reservoir releases and net draft-on-storage as required to modify the projected system to meet the quality criteria.

(d) Adjust net draft-on-storage as required to compensate for problems of synchronization of releases and downstream needs and conveyance losses. This suggested regulation is termed recommended annual draft-on-storage.

(3) Establishment of the base system involves establishing a network of flow and quality conditions without flow regulation for quality control. It includes establishing in logical downstream sequence the hydrologic and established or authorized water use and management components affecting quality, and the locations in the system where stream deficiencies for quality control are to be computed. To compile quantity and quality data for the component of the base system, the analyst must draw a representative sample of the possible events that could occur. Although there are numerous ways of drawing such a sample, a convenient and effective way is to array unpredictable events by magnitude; divide them into a convenient number of strata (groups); and take the median of each group as representative of that group. Such a sample adequately describes the array of probable events, and each item in the sample has an equal chance of occurrence in any one year. Usually, five strata will suffice, with their respective median taken as the event having exceedence probabilities of 0.1, 0.3, 0.5, 0.7, and 0.9. The procedure is as follows:

(a) As a first step, low-flow frequency graphs of annual mean stream flows at the critical points in the study area are constructed. Annual means based on climatic year (April-March) are a little better for regulation studies than annual water-year means (October-September).

(b) Typical monthly distribution of annual uncontrolled runoff is determined. The suggested procedure involves selecting a gaging station that has a reasonably long-term record and is representative of the area under study; establish the median monthly flow for each month; and compute the distribution of median monthly means as a ratio to annual mean flows.

(c) Determine the necessary quality and stream flow inputs to the base system.

(d) Assemble the data on projected increases in waste loading, stream depletions, etc., over and above those reflected in the base system.

(e) Compute the necessary base system flow and quality data for critical points.

(f) Project flow and quality needs at the critical points.

(g) Determine reservoir releases to meet quality needs at critical periods.

(h) Compute draft-on-storage required ($\Delta_s = Q_o - Q_i$).

(4) In his discussion, Mr. Rainwater claims that presentation of stream flow regulation needs in terms of annual Δ_s has several desirable attributes. It gives the quantity of water needed in storage that should be available each year to control, when needed, stream quality. As such, it embodies the concept of "flow regulation for quality control, including monitoring and control mechanics in contrast to maintaining some prescribed flow regimen." Thus, in water-short areas, water would not be wasted by releases when not needed. The Δ_s and the attendant benefits can be moved by the construction agencies from one reservoir site to another having comparable quality of releases or divided among several reservoir sites. This knowledge of where and how much draft-on-storage is needed in the basin gives the construction agencies some flexibility and direction in developing future site studies.

3. EXPLANATION OF RAINWATER METHOD

The following is an explanation of the Rainwater method, as utilized by Region VI, Public Health Service, in its work for the St. Louis District study on Meramec River Basin, Missouri. The Public Health Service in its analysis first established the base system by dividing the basin into sub-basins that reflect hydraulic aspects and flow control. Sub-basins selected were:

a. Upper basin.

(1) Big River Sub-basin.

(2) Upper Meramec River Sub-basin.

(3) Bourbeuse River Sub-basin.

b. Lower basin, which consisted solely of the lower portion of the Meramec River.

Each sub-basin was then divided into reaches of analysis and further broken down into load centers. These load centers were points that were selected to reflect sources of induced pollutants and were representative of selected population distribution centers. The present characteristics of the load centers were then defined in terms of population and water usage, expressed in terms of gallons per capita per

day. This gave a representation of the induced pollutant load that would have to be assimilated by the stream, assuming primary and secondary treatment in place. Projections were then made of the anticipated population growth in all parts of the basin on a time-phase basis. In conjunction with these population extrapolations, increased expected water use was also projected within the limits of the projections made by the U. S. Senate Select Committee. The product (population times water usage per capita) of these projections gave a basis for anticipated pollutant loads that were subsequently modified by anticipated mineral and organic pollutants to be anticipated from the industrial and rural aspects of the basin. To determine water quality requirements, the Public Health Service first determined the water supply (M&I) requirements and assumed that these demands were met and in place. The total water quality flow requirements (Q_t) were determined as the stream flow required to provide the necessary dilution to obtain a stream quality equal to 5 parts per million BOD. Its determination was based on the assumption that primary and secondary treatment had been provided the waste effluent at the discharge point or load centers. To determine the required stream flow (Q_o) necessary to meet the total flow requirements, the following formula was used: $Q_o = Q_t - Q_r$. Q_t was furnished on a seasonal basis, which recognized a temperature sensitive aspect, and was established in relation to water temperature. In the case of the Meramec Basin study, seasonal breakdowns were: a summer season of four months - June, July, August, and September; a spring and fall season of five months - March, April, May, October, and November; and a three-month winter season - December, January, and February. The return flow, Q_r, represents a portion of the M&I water returned to the stream at the selected load center, and can be either a positive or negative quantity, depending upon its source. In the case of the Meramec study, the return flow, Q_r, was a subtractive quantity since the Public Health Service assumed that the M&I waters in the upper basin came from underground water sources that were independent of stream flows, i.e., induction of flows from an outside water source independent of stream flows. The return flow was assumed constant for all three seasons, recognizing a time-lag aspect. Based on the above, the required stream needs, Q_o, were determined for each load center for the time periods involved in each analysis. Once these demands were established, they were converted from gpm to c.f.s. The Public Health Service then determined the amount of supplemental storage that would have to be furnished by the use of the formula $Q_o - Q_i = \Delta_s$, where:

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According to Mr. Rainwater, these flows are representative of the typical monthly distribution of annual uncontrolled runoff (see subparagraph 2b(3)(b)). Shown at the end of line 1 is the annual or yearly mean of the median flows. This was determined by summating the median monthly flows and dividing by 12. Line 2 shows the ratio of the individual monthly median flows to the annual or yearly mean of median monthly flows. Line 3 shows the annual flow at the Eureka, Missouri, gage that has a 5 percent probability of occurrence. This 5 percent probability flow was selected from an analysis by Public Health Service of the lower portion of a low-flow duration curve drawn for Eureka, Missouri, gage, and was equal to 1,320 c.f.s. for water quality. Line 4 represents the theoretical monthly flow having a 5 percent probability of occurrence (Q_i). This theoretical monthly flow was computed by multiplying the ratio shown in line 2 times the annual flow at Eureka for the corresponding probability. Shown in parentheses is a theoretical monthly flow for 2 percent probability (water supply). Accordingly, by use and definition, the Q_i shown in line 4 for each month represents the uncontrolled stream flow that would occur 95 percent of the time (water quality) or 98 percent of the time (water supply) for the load center or reach of stream under consideration.

b. Part B. Shown in Part B are the computations used to determine supplemental storage required for water quality control in a reservoir located upstream from the reach studied. This annual requirement, referred to as "draft-on-storage," was computed by the formula $\Delta_s = Q_o - Q_i$. Line 1 shows the monthly flow (Q_o), on a seasonal basis, needed to maintain a BOD stream requirement of 5 parts per million. Line 2 shows the theoretical flow requirements (Q_i) computed in Part A above. Line 3 shows the draft-on-storage for the climatic year. In this example, the stream theoretically required supplementation by reservoir for only three months during the climatic year. Total requirements equal 1,492 c.f.s. for three months in a year. Storage was computed as equal to 1,492, the monthly flow deficiency, times 30 days per month, times 2 acre-feet per c.f.s. or a total of 90,000 acre-feet supplemental storage required.

c. Part C. Shown in Part C are statistical data prepared by the St. Louis District, based on 42 years of record for the Eureka, Missouri, gage. The mean monthly discharges for each month in each year of record studied were arrayed in descending order of occurrence. Based on this information, curves were drawn and percent chance of occurrence on a probability basis was established. (See Table 2). Line 1 of Part C shows the average or mean monthly flow. Line 2 shows the median (50 percent) of the mean monthly flows. Line 3 shows the statistical monthly flow having a 95 percent chance of occurrence. Line 4 shows the statistical monthly flow having a 98 percent chance of occurrence.

d. Part D. Part D shows the effects on draft-on-storage required when utilizing the same stream flow requirements (Q_o), but a revised uncontrolled stream flow having 95 percent chance of occurrence from a statistical, rather than a theoretically computed, basis. Draft-on-storage required (Δ_s) is approximately twice that computed by the Rainwater method.

5. DISCUSSION OF RAINWATER METHOD

There are several aspects of the methodology that are questionable when applied to basin analysis and reservoir operation. These theoretical points are discussed briefly below.

a. Probability aspect. Mr. Rainwater's method purports to determine the present unregulated flow for each month that has a 95 percent chance of occurrence. It is claimed (see subparagraph 2b(3)) that the monthly median flow is characteristic of the annual flow distribution pattern of the stream, and by use of a ratio of medians, the annual flow for any degree of protection can be redistributed and converted into a monthly limit. Analysis has indicated that for a stream that has erratic flow characteristics, the use of medians is not applicable. It is felt, however, that the use of medians may be applicable when a stream is partially controlled or when a stream has very little year-round flow fluctuation. It should be stressed that the methodology is keyed to determine the unregulated flow having a 95 percent chance of occurrence for each month. Thus, it is apparent that the monthly, not the annual or yearly, flow pattern is the controlling element for determining draft-on-storage. It is suggested that in lieu of using the median approach, an analysis of each monthly flow should be made, similar to that undertaken by the St. Louis District office. A statistical analysis based on an array of occurring flows listed in descending order should be made and the monthly flow for the particular degree of protection desired be determined.

b. Length or duration of low-flow period. The Rainwater methodology determines only the amount of base or supplemental storage required for a climatic year. No attempt has been made to recognize an extended low-flow period similar to that experienced in the Meramec Basin for the period 1952 to 1957. Reference is made to Bulletin 51, State of Illinois Department of Registration and Education, entitled "Low Flows of Illinois Streams for Impounding Reservoir Design," published by the Illinois State Water Survey, 1964. The following information concerning low-flow series is contained in the publication:

"Past experience in analysing the 1952-55 drought in Illinois revealed that impounding reservoirs in Illinois are frequently under draft and drawdown for periods in excess of one year and may possibly be subject to drawdowns for as long as five years. For this reason it was necessary that the series of low flow events be selected in a manner not restricted to the annual fluctuations of runoff. A partial duration series of low flow events was selected as being most flexible and meaningful in this type of analysis. However, the partial series was selected only after intensive study, comparison, and evaluation of both the partial series and the more common and more easily interpreted annual series. . ."

The adequacy of storage (draft-on-storage) recommended in the Public Health Service report, dated February 1964, for water quality control only was analyzed by the St. Louis District office for the period of record 1922 to 1959, using the actual daily flows at the Eureka, Missouri, gage. Using the Public Health Service seasonal stream flow requirements (monthly Q_o), it was found that the 90,000 acre-feet of supplemental storage was insufficient to meet the demands at least 13 out of the 38 years of record studied. Analysis indicated that once the storage was depleted, the only available flow was inflow from the drainage area above the control point. However, the lengths of some of these low-flow periods were of such magnitude as to prevent complete reservoir refilling. Consequently, a succession of drought years prevented the reservoir from providing low-flow regulation 95 percent of the time.

c. <u>Probability versus frequency of occurrence</u>. It has been noted that the Public Health Service uses the expressions "95 percent chance of occurrence" and "5 percent probability" interchangeably. Use of the 95 percent chance of occurrence means that in application of a low-flow duration curve, the selected flow is equalled or exceeded 95 percent of the time <u>for the period of record used.</u> This does not necessarily have any relationship to a 5 percent probability or a flow that is equal to or less than that experienced once every 20 years.

d. <u>Future stream depletion</u>. As was brought out in subparagraph 2a(3)(b), analysis of regulated needs should be based on future depleted or modified stream flows (Q_i). The flow to be augmented in the future will not necessarily be the same flow measured now, but will be depleted by the then existing water use and management. The

Rainwater method, as used by the Public Health Service Regional Office, determined a typical monthly distribution of annual uncontrolled runoff (Q_i) and used it as a constant for all future time periods. As far as could be ascertained, the flow requirements Q_t, Q_r, and/or Q_o were not modified to reflect factors of future stream depletion. Consequently, storage requirements for future needs would not be sufficient when viewed from anticipated future stream depletion.

e. Data obsolescence. Allied to the problem of future stream depletion is data obsolescence (see subparagraph 2a(3)(a)). Reference is made to the open-file report prepared by the U. S. Geological Survey. This low-water study, covering the period 24 September through 1 October 1953, brought out the fact that the flows in the Big River were far above average for the basin due to the effect of waste being discharged into the stream from the then existing mining operations. Since then, mining operations have decreased and the use of historic data unmodified, as was done in relation to the Meramec Basin report by the Public Health Service, would provide insufficient amounts for water quality control.

f. Minimum control. The Rainwater methodology provides supplemental flow requirements to maintain a BOD count of 5 parts per million on an annual basis and monthly control. It is questionable whether supplementing flows having a 95 percent chance of occurrence are sufficient. Because of the extended low-flow periods now being experienced, it is suggested that a minimum flow limitation be provided. Assuming the Public Health Service criterion is to avoid criticism for providing excessive storage for augmentation, a minimum limit related to a safe BOD count, e.g., three parts per million, should be provided as a critical low with time (days) limitations if needed so that absolute stream regulation can be maintained. Knowing how long the lower BOD limit could be maintained without any serious complications to the public safety would be helpful in routing the demands against any mass curve modified to the critical load center under study.

g. Use of same base natural flow. Mr. Rainwater has maintained that his draft-on-storage is the amount of storage to be provided by the construction agencies. However, where there is a need for both water supply and water quality control in the same reach, he has analyzed these demands (Q_o) separately, utilizing the same natural flow as a base (Q_i) to compare his demands. As a result, storage requirements for the combined demands, as estimated by the Corps, are far greater than the sum of storage provided for both the individual demands when analyzed separately over the same natural base flow.

h. Degree of flow guaranteed. The Regional Office of the Public Health Service indicated that the selected flow (Q_i) representing the unregulated stream flow varied with the purpose under study. In the case of stream regulation for water quality control, a stream flow (Q_i) having a theoretical frequency of occurrence of 95 percent was used. In the case of water supply, the frequency of occurrence selected was 98 percent. Several questions have arisen in conjunction with this degree of flow:

(1) In a reach where both water supply and water quality control are required, which percent frequency of occurrence governs?

(2) Local interests have indicated a desire for guaranteed water supply, at least as pertains to the maximum deficiency during the period of record. Since water supply is a reimbursable cost, it is questioned as to why frequency of occurrence of less than the maximum deficiency of the period of record was selected.

6. VIEWS OF ST. LOUIS DISTRICT

Review of the Rainwater methodology used by the Public Health Service to determine supplemental needs and applicable values or benefits, for either water supply and/or water quality, has led to the following conclusions:

a. Use of the theoretically computed flow (Q_i) representing the unregulated stream flow results in a storage requirement (Δ_s) and time of need, which are erroneous when analyzed using historical stream flow data on an annual basis and converted to a monthly basis. The theoretically computed draft-on-storage or, in the case of water quality alternatives, the amount of pollutants that would have to be pumped over and above the amount that could be assimilated by the unregulated stream flow (Q_i), is computed for only a climatic year and is based on quantities of flows that are not applicable for streams that have erratic flow characteristics. Use of the climatic year does not recognize extended low-flow drought periods. Furthermore, the theoretically computed Q_i does not necessarily depict the flow pattern of the stream, instead, as in the case of the Meramec River Basin flow, incorrectly credits the streams with greater monthly flows and assimilation capabilities for the degree of protection desired and results in greatly reduced supplemental needs and resulting benefits.

b. Benefits computed based on either the annual draft-on-storage or pumped increments of sewage are inadequate when viewed from two other aspects. The first aspect is the discount factor used in relation to time of need. Use of a higher computed unregulated flow (Q_i) places the time of need and provision per purpose far later than historical stream flow data indicate. The second factor is that the reduced requirement, as determined by the methodology, may lead to selection of an alternative means as the basis for benefit evaluation that is wholly inadequate and impractical for obtaining the required degree of protection when correlated to historical flow data and extended flow durations.

c. In reaches of streams where two supplemental flows (water quality and water supply) are required, evaluation of supplemental storage or flow needs should be made on a total demand basis with storage allocations to individual purposes apportioned on a first added-last added basis. The resultant individual supplemental flow requirements would then serve as the basis for benefit evaluation. This automatically avoids the error of using the same natural flow when computing the individual needs for both purposes, as was done by the Public Health Service in the Meramec report.

d. In apportioning the supplemental flow requirements per purpose under first added-last added basis (see subparagraph c above), care should be exercised regarding the routings made to compare natural flows versus demands. In the case of water supply, the minimum flow of record should be selected as a base to which water supply needs are added under the first added basis. This would assure an analysis depicting a condition that would safeguard the existing ripian rights and avoid a complete stream depletion by withdrawals.

e. Selection of pumping increments of sewage from one basin to another is questionable as to practicality and feasibility in use as an alternative for water quality benefit evaluation. Legal problems may arise, but more important, a study would be required to develop future growth and pollution controls on both streams to determine whether this transfer of pollutants could be undertaken without just a transferring of one pollutement problem from one basin to another.

f. Information obtained from the Public Health Service indicated that the following <u>average</u> temperatures for unregulated flows were used to define the seasonal breakdown for both water quality and water supply in the Meramec report: winter, 41°F; spring and fall, 59°F; summer 77°F. In its report dated February 1964, the

Public Health Service used the classic seasonal breakdown, i.e., a three-month winter period - December, January, and February; a three-month summer period - June, July, and August; and a six-month spring and fall period - March, April, May, September, October, and November. To determine the validity of this seasonal breakdown, an analysis by this District was undertaken using data obtained from the USGS Circular No. 216 entitled "Water Resources of the St. Louis Area, Missouri and Illinois," and water temperatures recorded at the water plant intake located on the Meramec River at Kirkwood, Missouri. A three-step analysis was made to define the seasonal breakdown. This analysis was based on first recognizing that the average temperature should be a true median point between the season's maximum and minimum temperatures; that the temperature differential for the maximum, average, and minimum in each season should be about the same; and that the range of the differential temperatures should be adjusted to reflect the effects of the appropriate season, i.e., the trend (recommended temperature ranges) would justify increasing or decreasing the flow requirements for water quality control. Results of this analysis were presented informally to the Public Health Service with the result that the definition of seasons on a monthly basis was changed and the revised monthly seasons were used in computing storage requirements and resulting benefits. However, with the increase in the number of low-flow periods that exceed a climatic year, it is felt that additional investigation and consideration should be given to further adjustment and refinement of the seasonal breakdown used by the Public Health Service since that agency equates water usage (M&I demands) and assimilation abilities (water quality requirements) to temperature aspects. This particular point becomes very important in determining supplemental flow requirements in a basin.

Prepared by
U. S. Army Engineer District,
St. Louis
11 August 1965

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE
560 Westport Road
Kansas City, Missouri 64111

PUBLIC HEALTH SERVICE
WS & PC Program

August 5, 1965

Colonel James B. Meanor, Jr.
District Engineer
St. Louis District
Corps of Engineers, U. S. Army
906 Olive Street
St. Louis, Missouri 63101

Re: LMSED-BM

Dear Colonel Meanor:

In accordance with Mr. Lawlor's letter of 30 July 1965, we submit the following background information concerning the need and benefit evaluations for water quality control in Reach M-7, the lower basin area of the Meramec River Basin in Missouri.

In estimating streamflow to be used in determining needs for water quality control, a 95 percent probability level was used instead of 90 percent, which is frequently used. This higher value was selected because of the expected complete urbanization of the area studied. Use of the 95% probability values increased the requirements.

The following table shows the expected population and quantity of sewage to be pumped.

Population and Sewage Pumped*

	1970	2020	2070
Population	130,000	620,000	2,000,000
Sewage Pumped MG/Year (Ave.)	100	3,000	8,000
Size of Pipelines	54"	66"	84"
Maximum Daily Pumpage Used in Design (MGD)	45	130	260

*Sewage to be pumped was estimated based on the monthly variation in the assimilating capacity of the unregulated flow (Q_1). The values in the report are the summation of all the incremental pumping requirements to handle the waste loadings which exceed the assimilative capacity of the unregulated flows established by a probability of occurrence. The critical flow is the low flow which will be exceeded 95 percent of the years.

Incl 2

Col. Meanor---8/5/65

In estimating the assimilating capacity of the stream in Reach M-7, the "Q_1", exceeded 95 percent of the time, was established by analysing all streamflow data of record using median monthly values on a climatic year basis. The return flow from upstream municipal ground water supplies will augment the streamflow and will be available for quality control in Reach M-7.

Estimated Unregulated Flow in 2070
That Will Be Exceeded 95 Percent of the Years

	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
MGD	962	893	609	442	405	381	256	337	381	497	562	1080

The pumping stations and pipelines were sized on the basis of need for each of the periods 1970, 2020, and 2070 to handle the maximum daily flows to be pumped. The following table is the summary of the capital, operating and maintenance costs, and their amortized value of the pumping stations and pipelines.

Pumping Stations and Pipeline Costs

Construction Cost $	Year of First Need	Cost Discounted at 3% to 1970 $	Annual Cost (1970 to 2070) Amortized @ 3% $
6,800,000	1990	3,765,000	119,000
44,000*		736,000	23,300
8,500,000	2020	1,939,000	61,400
107,000*		628,000	20,000
11,000,000	2050	1,034,000	32,700
104,000*		145,000	4,600
		TOTAL	261,000

*Annual operation and maintenance costs from year of first need to end of study period.

Col. Meanor---8/5/65

The estimated cost of pumping stations and pipelines was found to be the most economical of the several most likely alternatives studied, and was, therefore, used as the benefit value.

We trust the above information will answer the question of the Board of Engineers for Rivers and Harbors, Washington, D.C.

Sincerely,

HERBERT C. CLARE, P.E.
Regional Program Director
Water Supply and Pollution Control

cc: DWSPC - Attn: Krause

Incl 3

Reformulation of #9 Irondale Reservoir

A. Pertinent data	Summary report	Revised	Difference
Top dam elevation (m.s.l.)	887	884	3
Spillway crest elevation (ft)	860	855	5
Normal pool elevation (ft)	855	850	5
Minimum conservation pool (100-year sediment)	796	796	-
Storage (ac-ft)			
Total	161,000	140,000	21,000
Flood control	23,900	23,900	-
Joint-use	137,100	116,100	21,000
Sediment	5,800	5,800	-
Net joint-use	131,300	110,300	21,000
Pool areas (acres)			
Maximum spillway surcharge	8,000	7,500	500
Flood control pool	5,100	4,650	450
Normal pool	4,600	4,100	500
Minimum conservation pool	500	500	-
Dam dimensions			
Crest length (ft)	4,050	3,960	90
Base width (ft)	722	700	22
Volume (cubic yard)	1,273,000	1,171,000	102,000

Reformulation of #9 Irondale Reservoir (cont'd)

B. Cost estimate	Summary report	Revised	Difference
01. Lands & damages	$ 1,980,000	$ 1,740,000	$ -240,000
02. Relocations	3,831,000	3,180,000	-651,000
03. Reservoir	235,000	230,000	- 5,000
04. Dams	5,019,000	4,770,000	-249,000
06. Fish & wildlife facilities	11,000	10,000	- 1,000
08. Roads, railroads & bridges	367,000	370,000	3,000
14. Recreational facilities	537,000	400,000	-137,000
19. Buildings, grounds & utilities	233,000	220,000	- 13,000
20. Permanent operating equipment	164,000	160,000	- 4,000
30. Engineering & design	1,218,000	1,100,000	-118,000
31. Supervision & administration	805,000	720,000	- 85,000
Total	14,400,000	12,900,000	$-1,500,000

C. Benefits

Flood control - total	$ 63,400	$ 63,400	$ -
Meramec River	(63,400)	(63,400)	-
Mississippi River	-	-	-
Water quality	320,000	320,000	-
Water supply	9,400	7,600	- 1,800
Recreation - total	590,500	448,500	-142,000
General	(365,100)	(243,600)	(-121,500)
Fishing and hunting	(225,400)	(204,900)	(- 20,500)
Navigation	4,000	4,000	-
Total gross benefits	$987,300	$843,500	$-143,800
Less negative benefits	800	800	-
Total net benefits	$986,500	$842,700	$-143,800

D. Benefit-cost ratios

Annual economic cost - $627,500

Annual benefits - $842,700

Benefit-cost ratio - 1.3

Reformulation of #9 Irondale Reservoir (cont'd)

E. Allocation of costs	Flood control	Water quality	Water supply	Total recreation	Navigation	Total
Average annual benefits	63,400	320,000	7,600	448,500	4,000	843,500
Average annual charges (financial)	57,400	226,200	6,700	304,900	2,800	598,000
Benefit-cost ratio	1.1	1.4	1.1	1.5	1.4	1.4
Allocated first costs	1,399,000	5,470,000	138,000	5,824,000	69,000	12,900,000
Allocated O&M *	8,700	35,800	1,900	102,200	400	149,000

*Includes replacement costs.

Reformulation of #9 Irondale Reservoir (cont'd)

F. Apportionment of costs (costs in thousand dollars)

	First cost	O&M
Federal		
Flood control		
Cost	1,399	8.7
Percent	10.84	5.84
Water quality		
Cost	5,470	35.8
Percent	42.40	24.03
Recreation		
Cost	4,133	61.2
Percent	32.04	41.07
Navigation		
Cost	69	0.4
Percent	0.54	0.27
Subtotal		
Cost	11,071	106.1
Percent	85.82	71.21
Non-Federal		
Water supply		
Cost	138	1.9
Percent	1.07	1.27
Recreation		
Cost	1,691	41.0
Percent	13.11	27.52
Subtotal		
Cost	1,829	42.9
Percent	14.18	28.79
Total project costs	12,900	149.0

Table 1
Water quality determination
PHS computations for draft on storage
(Reach M-7)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
A. Based on Eureka Gage per PHS													
Ave. 32 yrs. of record, to 1950 incl.													
1. Median flows	4,394	3,267	2,472	1,260	949	769	819	1,245	1,616	2,262	2,480	4,351	$\frac{25,884}{12}$ = 2,157
2. Ratio = $\frac{\text{monthly median flow}}{\text{yearly mean of median monthly flows}}$	2.04	1.51	1.15	0.58	0.44	0.36	0.38	0.57	0.75	1.05	1.15	2.02	
3. Annual flow @ Eureka having a 5% chance of occurrence or prob. (from duration curve)													5% @ 1,320 c.f.s. (2% @ 1,100 c.f.s.)
4. Theoretical monthly flow having a 5% prob. of occurrence (step 2 x step 3)	2,693	1,993	1,518	766	581	475	502	752	990	1,386	1,518	2,666	
@2%	(2,240)	(1,661)	(1,155)	(638)	(484)	(396)	(418)	(627)	(825)	(1,159)	(1,265)	(2,222)	
B. Computations for draft on storage													
1. Demand, Q_o (2,070)	487	487	1,410	1,410	1,410	487	487	487	200	200	200	380	
2. Theoretical flow, 5% prob. (Qi) (see A-4 above)	2,689	1,990	1,517	764	578	473	502	753	986	1,383	1,517	2,660	
3. Draft on storage required (c.f.s.)	-	-	-	646	832	14	-	-	-	-	-	-	1,492
(Δ_s) Storage	(646+832+14=1,492) x 30 (days per month) x 2 (acre-ft. per c.f.s.) = 90,000 acre-feet - base storage for water quality - M-7												
C. Corps of Engineers data (42 years of record, 1922-1963 incl.)													
1. Mean monthly flows	5,882	5,403	4,129	2,111	1,132	1,094	1,417	1,972	2,224	2,979	3,264	4,840	
2. Median of mean monthly flows	3,934	4,141	2,633	1,125	890	662	704	1,213	1,601	1,990	2,490	4,544	
3. Monthly flow - 95% prob.	1,110	925	675	475	396	390	428	510	585	562	650	950	
4. Monthly flow - 98% prob.	965	820	585	355	360	295	380	485	490	500	565	625	
D. PHS demand vs Corps of Engineers 95% prob. flows													
Q_o	487	487	1,410	1,410	1,410	487	487	487	200	200	200	380	
Q_i	1,110	925	675	475	396	390	428	510	585	562	650	950	
Δ_s (c.f.s.)	-	-	735	935	1,014	97	59	-	-	-	-	-	2,840
storage			2,840 x 30 x 2 = 170,400 acre-feet										

Table 2

Statistical array
Mean monthly discharges - April
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
22,600	1	2.38
20,000	2	4.76
15,500	3	7.14
15,400	4	9.52
12,770	5	11.90
12,390	6	14.29
9,060	7	16.67
8,551	8	19.05
8,044	9	21.43
7,513	10	23.81
7,390	11	26.19
7,178	12	28.57
6,770	13	30.95
6,387	14	33.33
5,880	15	35.72
4,705	16	38.10
4,650	17	40.48
4,363	18	42.86
4,330	19	45.24
4,138	20	47.62
3,934	21	50.00
3,901	22	52.38
3,883	23	54.76
3,737	24	57.14
3,663	25	59.52
3,568	26	61.91
3,381	27	64.29
3,370	28	66.67
3,357	29	69.05
2,953	30	71.43
2,790	31	73.81
2,750	32	76.19
2,675	33	78.57
2,388	34	80.95
2,350	35	83.34
2,126	36	85.72
2,102	37	88.10
1,798	38	90.48
1,700	39	92.86
1,100	40	95.24
969	41	97.62
945	42	100.00

Statistical array
Mean monthly discharges - May
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
17,730	1	2.38
15,860	2	4.76
15,430	3	7.14
15,100	4	9.52
13,600	5	11.90
11,400	6	14.29
10,770	7	16.67
9,081	8	19.05
8,976	9	21.43
8,289	10	23.81
8,010	11	26.19
6,263	12	28.57
6,240	13	30.95
5,066	14	33.33
4,980	15	35.72
4,762	16	38.10
4,659	17	40.48
4,595	18	42.86
4,431	19	45.24
4,187	20	47.62
4,141	21	50.00
3,249	22	52.38
3,240	23	54.76
3,140	24	57.14
3,072	25	59.52
2,860	26	61.91
2,799	27 & 28	66.67
2,720	29	69.05
2,510	30	71.43
2,077	31	73.81
1,960	32	76.19
1,759	33	78.57
1,752	34	80.95
1,747	35	83.34
1,562	36	85.72
1,450	37	88.10
1,242	38	90.48
970	39	92.86
924	40	95.24
822	41	97.62
708	42	100.00

Statistical array
Mean monthly discharges - June
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
18,070	1	2.38
16,000	2	4.76
14,800	3	7.14
13,890	4	9.52
11,490	5	11.90
8,350	6	14.29
7,940	7	16.67
7,539	8	19.05
7,188	9	21.43
4,880	10	23.81
4,800	11	26.19
4,241	12	28.57
3,580	13	30.95
3,433	14	33.33
3,394	15	35.72
3,230	16	38.10
3,199	17	40.48
3,110	18	42.86
2,874	19	45.24
2,830	20	47.62
2,633	21	50.00
2,145	22	52.38
1,952	23	54.76
1,836	24	57.14
1,800	25	59.52
1,776	26	61.91
1,522	27	64.29
1,470	28	66.67
1,420	29	69.05
1,405	30	71.43
1,338	31	73.81
1,260	32	76.19
1,020	33	78.56
943	34	80.95
922	35	83.34
914	36	85.72
849	37	88.10
820	38	90.48
803	39	92.86
673	40	95.24
590	41	97.62
503	42	100.00

Statistical array
Mean monthly discharges - July
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
12,600	1	2.38
11,500	2	4.76
5,659	3	7.14
5,631	4	9.52
4,983	5	11.90
4,455	6	14.29
3,250	7	16.67
2,901	8	19.05
2,880	9	21.43
2,744	10	23.81
2,677	11	26.19
2,255	12	28.57
2,254	13	30.95
1,549	14	33.33
1,471	15	35.72
1,466	16	38.10
1,450	17	40.48
1,420	18	42.86
1,260	19	45.24
1,142	20	47.62
1,125	21	50.00
1,078	22	52.38
999	23	54.76
985	24	57.14
844	25	59.52
823	26	61.91
726	27	64.29
713	28	66.67
692	29	69.05
689	30	71.43
685	31	73.81
629	32	76.19
620	33	78.57
614	34	80.95
604	35	83.34
601	36	85.72
553	37	88.10
506	38	90.48
497	39	92.86
474	40	95.24
356	41	97.62
318	42	100.00

Statistical array
Mean monthly discharges - August
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
4,286	1	2.38
4,175	2	4.76
2,780	3	7.14
2,120	4	9.52
2,062	5	11.90
1,855	6	14.29
1,710	7	16.67
1,640	8	19.05
1,510	9	21.43
1,474	10	23.81
1,200	11	26.19
1,077	12	28.57
1,073	13	30.95
1,061	14	33.33
1,056	15	35.72
1,051	16	38.10
1,045	17	40.48
1,024	18	42.86
949	19 & 20	47.62
890	21	50.00
820	22	52.38
772	23	54.76
771	24	57.14
758	25	59.52
733	26	61.91
729	27	64.29
654	28	66.67
648	29	69.05
612	30	71.43
554	31	73.81
551	32	76.19
544	33	78.57
526	34	80.95
510	35	83.34
488	36	85.72
473	37	88.10
428	38	90.48
407	39	92.86
396	40	95.24
386	41	97.62
255	42	100.00

Statistical array
Mean monthly discharges - September
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
5,478	1	2.38
4,396	2	4.76
3,597	3	7.14
3,268	4	9.52
2,682	5	11.90
1,850	6	14.29
1,430	7	16.67
1,390	8	19.05
1,377	9	21.43
1,010	10	23.81
921	11	26.19
912	12	28.57
870	13	30.95
798	14 & 15	35.72
784	16	38.10
773	17	40.48
765	18	42.86
756	19	45.24
684	20	47.62
662	21	50.00
653	22	52.38
640	23	54.76
632	24	57.14
616	25	59.52
615	26	61.91
592	27	64.29
586	28	66.67
584	29	69.05
560	30	71.43
545	31	73.81
504	32	76.19
496	33	78.57
486	34	80.95
485	35	83.34
477	36	85.72
475	37	88.10
471	38	90.48
408	39	92.86
390	40	95.24
297	41	97.62
244	42	100.00

Statistical array
Mean monthly discharges - October
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
12,120	1	2.38
3,850	2	4.76
3,760	3	7.14
3,600	4	9.52
3,019	5	11.90
2,820	6	14.29
2,620	7	16.67
2,407	8	19.05
1,740	9	21.43
1,600	10	23.81
1,231	11	26.19
1,149	12	28.57
1,120	13	30.95
1,062	14	33.33
1,031	15	35.72
1,014	16	38.10
847	17	40.48
791	18	42.86
717	19	45.24
705	20	47.62
704	21	50.00
689	22	52.38
684	23	54.76
675	24	57.14
653	25	59.52
638	26	61.91
622	27	64.29
592	28	66.67
589	29	69.05
578	30	71.43
575	31	73.81
573	32 & 33	78.57
571	34	80.95
569	35	83.34
548	36	85.72
504	37	88.10
438	38	90.48
436	39	92.86
427	40	95.24
418	41	97.62
239	42	100.00

Statistical array
Mean monthly discharges - November
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
7,317	1	2.38
7,086	2	4.76
5,790	3	7.14
5,209	4	9.52
5,070	5	11.90
4,660	6	14.29
4,507	7	16.67
3,830	8	19.05
3,390	9	21.43
2,312	10	23.81
1,973	11	26.19
1,943	12	28.57
1,932	13	30.95
1,930	14	33.33
1,822	15	35.72
1,638	16	38.10
1,569	17	40.48
1,382	18	42.86
1,278	19	45.24
1,224	20	47.62
1,213	21	50.00
1,212	22	52.38
1,140	23	54.76
939	24	57.14
927	25	59.52
913	26	61.91
882	27	64.29
865	28	66.67
829	29	69.05
821	30	71.43
786	31	73.81
686	32	76.19
644	33	78.57
641	34	80.95
632	35	83.34
630	36	85.72
629	37	88.10
587	38	90.48
511	39	92.86
510	40	95.24
486	41	97.62
464	42	100.00

Statistical array
Mean monthly discharges - December
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
9,296	1	2.38
7,250	2	4.76
5,380	3	7.14
4,436	4	9.52
3,954	5	11.90
3,782	6	14.29
3,730	7	16.67
3,660	8	19.05
3,550	9	21.43
3,400	10	23.81
3,340	11	26.19
3,280	12	28.57
3,012	13	30.95
2,360	14	33.33
2,240	15	35.72
2,145	16	38.10
1,917	17	40.48
1,811	18	42.86
1,700	19	45.24
1,630	20	47.62
1,601	21	50.00
1,506	22	52.38
1,469	23	54.76
1,340	24	57.14
1,255	25	59.52
1,250	26	61.91
1,167	27	64.29
1,164	28	66.67
1,125	29	69.05
1,100	30	71.43
991	31	73.81
870	32	76.19
826	33	78.57
805	34	80.95
791	35	83.34
711	36	85.72
690	37	88.10
670	38	90.48
650	39	92.86
581	40	95.24
511	41	97.62
426	42	100.00

Statistical array
Mean monthly discharges - January
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
17,320	1	2.38
9,918	2	4.76
8,920	3	7.14
7,651	4	9.52
5,668	5	11.90
5,540	6	14.29
4,490	7	16.67
4,200	8	19.05
4,024	9	21.43
3,945	10	23.81
3,867	11	26.19
3,340	12	28.57
2,903	13	30.95
2,750	14	33.33
2,748	15	35.72
2,553	16	38.10
2,414	17	40.48
2,323	18	42.86
2,284	19	45.24
2,240	20	47.62
1,990	21	50.00
1,939	22	52.38
1,925	23	54.76
1,820	24	57.14
1,790	25	59.52
1,637	26	61.91
1,622	27	64.29
1,380	28	66.67
1,370	29	69.05
1,240	30	71.43
1,178	31	73.81
1,038	32	76.19
976	33	78.57
953	34	80.95
915	35	83.34
768	36	85.72
758	37	88.10
665	38	90.48
572	39	92.86
562	40	95.24
530	41	97.62
374	42	100.00

Statistical array
Mean monthly discharges - February
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
10,350	1	2.38
8,428	2	4.76
8,251	3	7.14
7,090	4	9.52
6,588	5	11.90
6,529	6	14.29
6,380	7	16.67
6,232	8	19.05
4,810	9	21.43
4,310	10	23.81
4,210	11	26.19
4,149	12	28.57
3,951	13	30.95
3,850	14	33.33
3,840	15	35.72
3,186	16	38.10
3,060	17	40.48
2,652	18	42.86
2,610	19	45.24
2,532	20	47.62
2,490	21	50.00
2,470	22	52.38
2,309	23	54.76
2,280	24	57.14
2,065	25	59.52
2,023	26	61.91
1,949	27	64.29
1,948	28	66.67
1,847	29	69.05
1,750	30	71.43
1,523	31	73.81
1,453	32	76.19
1,390	33	78.57
1,256	34	80.95
1,143	35	83.34
1,120	36	85.72
1,117	37	88.10
1,107	38	90.48
1,100	39	92.86
620	40	95.24
569	41	97.62
538	42	100.00

Statistical array
Mean monthly discharges - March
Meramec River, Mo. - Eureka, Mo., gage

Discharge c.f.s.	Occurrence	Percent occurrence
13,390	1	2.38
9,949	2	4.76
9,855	3	7.14
7,797	4	9.52
7,330	5	11.90
7,320	6	14.29
7,233	7	16.67
7,224	8	19.05
7,082	9	21.43
6,960	10	23.81
6,910	11	26.19
6,739	12	28.57
6,706	13	30.95
6,624	14	33.33
6,467	15	35.72
6,250	16	38.10
5,591	17	40.48
4,757	18	42.86
4,715	19	45.24
4,550	20	47.62
4,544	21	50.00
4,520	22	52.38
4,182	23	54.76
4,054	24	57.14
4,030	25	59.52
3,647	26	61.91
3,354	27	64.29
3,120	28	66.67
3,071	29	69.05
3,060	30	71.43
3,007	31	73.81
2,815	32	76.19
2,580	33	78.57
2,270	34	80.95
2,253	35	83.34
2,194	36	85.72
1,900	37	88.10
1,570	38	90.48
1,516	39	92.86
949	40	95.24
671	41	97.62
514	42	100.00

Cost Allocation Studies

Irondale Reservoir

Determination of Separable Costs

A. Total Separable Cost

1. Flood Control (Normal Pool Area = 4,100 acres = 100%)

   a. Separable cost = $598,000 -$552,700 = $45,300

2. Water Quality

   a. Separable cost = $598,000 -$548,200 = $49,800

   b. But without water quality, the normal pool is reduced to 3,600 acres or $\frac{500}{4,100}$ = 12% and results in the following benefit loss: $843,500 -$470,500 = $373,000, of which $320,000 is water quality, $3,900 is navigation, $29,200 is general recreation and $19,900 is Fish and Wildlife. Total recreation = $49,100

   c. Modified separable cost = $49,800 -$12% of $62,500 (annual specific cost of recreation) or $7,500) = $42,300

3. Water Supply

   a. Separable cost = $598,000 -$424,000 = $174,000

   b. But without water supply, the normal pool is reduced to 2,000 acres or $\frac{2,100}{4,100}$ = 51% and results in the following benefit loss: $843,500 -$626,900 = $216,600, of which $7,600 is water supply, $100 is navigation, $124,200 is general recreation and $84,700 is Fish and Wildlife. Total recreation = $208,900

   c. Modified separable cost = $174,000 -(51% of $62,500 (annual specific cost of reduction) or $31,900) = $142,100

B. Operation and Maintenance (including supervision and administration costs)

1. Flood Control

a. Separable cost = $129,000 -$123,000 = $6,000

2. Water Quality

a. Separable cost = $129,000 -$116,000 = $13,000

b. Modified separable cost = $13,000 -(12% of $34,000) = $8,900

3. Water Supply

a. Separable cost = $129,000 -$72,000 = $57,000

b. Modified separable cost = $57,000 -(51% of $34,000) = $39,700

C. Replacement Costs

1. Flood Control

a. Separable cost = $20,000 -$19,000 = $1,000

2. Water Quality

a. Separable cost = $20,000 -$18,000 = $2,000

b. Modified separable cost = $2,000 -(12% of $7,000) = $1,200

3. Water Supply

a. Separable cost = $20,000 -$9,000 = $11,000

b. Modified separable cost = $11,000 -(51% of $7,000) = $7,400

Cost allocation - #9 Irondale Reservoir
Summary of construction expenditures, annual financial charges and benefits (dollars)

	Multiple-purpose project				Alternate single-purpose project				Alternate multiple-purpose projects			
	Specific costs											
	General recreation	Fish & wildlife	Joint-use costs	Total costs	Flood control	Water quality	Water supply	Recreation	Flood control, water quality, recreation, and navigation	Flood control, water supply, recreation, and navigation	Water quality, water supply, recreation, and navigation	Flood control, water supply, water quality, and navigation
01. Lands and damages	140,000	-	1,600,000	1,740,000	355,000	419,000			1,064,000	1,520,000	1,440,000	1,650,000
02. Relocations	-	-	3,800,000	3,800,000	1,361,000	1,663,000			2,262,000	3,304,000	3,272,600	3,800,000
03. Reservoir	-	-	275,000	275,000	205,000	220,000			264,000	257,000	255,000	275,000
04. Dams	-	-	5,699,000	5,699,000	4,697,000	4,852,000			5,225,000	5,420,000	5,377,000	5,699,000
06. Fish & wildlife facilities	-	12,000	-	12,000	-	14,000			13,000	13,[illegible]00	13,000	12,000
08. Roads, railroads & bridges	-	-	442,000	442,000	451,000	451,000			446,000	464,000	443,000	422,000
14. Recreational facilities	478,000	-	-	478,000	-	-			348,000	425,000	484,000	-
19. Buildings, grounds & utilities	-	-	263,000	263,000	64,000	64,000			304,000	303,000	303,000	252,000
20. Permanent operating equipment	-	-	191,000	191,000	97,000	97,000			214,000	214,000	213,000	190,000
Total for project	618,000	12,000	12,270,000	12,900,000	7,230,000	7,780,000	11,200,000	7,900,000	10,000,000	11,900,000	11,800,000	12,300,000
Investment												
Construction period (years)				4	3	3	4	3	3	4	4	4
Interest during construction	18,600	800	766,900	806,300	338,900	364,700	700,000	370,300	468,800	743,800	737,500	768,800
Total investment	636,600	12,800	13,036,900	13,706,300	7,568,900	8,144,700	11,900,000	8,270,300	10,468,800	12,643,800	12,537,500	13,068,900
Annual charges												
Interest & amortization	21,500	400	427,100	449,000	248,000	266,800	389,800	270,900	343,000	414,200	410,700	428,100
Operation & maintenance	32,000	-	87,000	119,000	49,800	50,200	58,000	65,000	66,000	107,000	114,000	87,000
Supervision & administration	2,000	-	8,000	10,000	5,200	[illegible],800	6,000	6,000	6,000	9,000	9,000	8,000
Replacement costs	7,000	-	13,000	20,000	1,000	2,000	3,000	12,000	9,000	18,000	19,000	13,000
Total annual charges	62,500	400	535,100	598,000	304,000	324,800	456,800	353,900	424,000	548,200	552,700	536,100
Benefits												
Flood control				63,400	63,400				63,400	63,400	-	63,400
Water quality - local				320,000		320,000			320,000	-	320,000	320,000
- N-7				-					-	-	-	-
Water supply - N-7				7,600			7,600		-	7,600	7,600	7,600
General recreation				243,600				243,600	119,400	214,400	243,600	-
Fish & wildlife recreation				204,900				204,900	120,200	185,000	204,900	38,900
Navigation				4,000					3,900	100	4,000	4,000
Total annual benefits				843,500	63,400	320,000	7,600	448,500	626,900	470,500	780,100	433,[illegible]00

Cost allocation - #9 Irondale Reservoir
allocation by separable costs - remaining benefits method

Project purposes	Flood control	Water quality	Water supply	Total recreation	General recreation	Total fish & wildlife	Navigation	Total
Allocation of annual charges								
Benefits	63,400	320,000	7,600	448,500	243,600	204,900	4,000	843,500
Alternate costs	304,000	324,800	456,800	353,900	192,200	161,700	4,000	1,443,500
Benefits limited by alternate costs	63,400	320,000	7,600	353,900	192,200	161,700	4,000	748,900
Initial separable costs	45,300	-	-	62,900	62,500	400	-	108,200
Applicable benefits before dual costs	-	320,000	-	49,100	29,200	19,900	3,900	373,000
Allocated dual cost (water quality block storage)	-	36,300	-	5,600	3,300	2,300	400	42,300
Applicable benefits before dual costs	-	-	7,600	208,900	124,200	84,700	100	216,600
Allocated dual cost (water supply block storage)	-	-	5,000	137,000	81,500	55,500	100	142,160
Total separable cost	45,300	36,300	5,000	205,500	147,300	58,200	500	292,600
Remaining benefits	18,100	283,700	2,600	148,400	44,900	103,500	3,500	456,300
Allocated residual cost	12,100	189,900	1,700	99,400	30,100	69,300	2,300	305,400
Total allocation of project cost	57,400	226,200	6,700	304,900	177,400	127,500	2,800	598,000
Benefit-cost ratio (financial)	1.1	1.4	1.1	1.5	1.4	1.6	1.4	1.4
Allocation of operation and maintenance including supervision & administration costs								
Initial separable costs	6,000	-	-	34,000	34,000	-	-	40,000
Allocated dual costs (water quality block)	-	7,600	-	1,200	700	500	100	8,900
Allocated dual costs (water supply block)	-	-	1,400	38,300	22,800	15,500	-	39,700
Total separable cost	6,000	7,600	1,400	73,500	57,500	16,000	100	88,600
Allocated residual cost	1,600	25,100	200	13,200	4,000	9,200	300	40,400
Total allocation	7,600	32,700	1,600	86,700	61,500	25,200	400	129,000
Allocation of replacement costs								
Initial separable costs	1,000	-	-	7,000	7,000	-	-	8,000
Allocated dual costs (water quality block)	-	1,000	-	200	100	100	-	1,200
Allocated dual costs (water supply block)	-	-	300	7,100	4,200	2,900	-	7,400
Total separable cost	1,000	1,000	300	14,300	11,300	3,000	-	16,600
Allocated residual cost	100	2,100	-	1,200	400	800	-	3,400
Total allocation	1,100	3,100	300	15,500	11,700	3,800	-	20,000
Allocation of investment								
Annual investment	48,700	190,400	4,800	202,700	104,200	98,500	2,400	449,000
Allocated investment	1,486,600	5,812,200	146,500	6,187,700	3,180,900	3,006,800	73,300	13,706,300
Allocation of construction expenditures								
Specific investment	-	-	-	669,400	656,600	12,800	-	669,400
Investment in joint-use facilities	1,486,600	5,812,200	146,500	5,518,300	2,524,300	2,994,000	73,300	13,036,900
Interest during construction on joint-use facilities	87,500	341,900	8,600	324,600	148,500	176,100	4,300	766,900
Construction expenditures in joint-use facilities	1,399,100	5,470,300	137,900	5,193,700	2,375,800	2,817,900	69,000	12,270,000
Percent of construction expenditures on joint-use facilities	11.403	44.583	1.124	-	19.363	22.965	0.562	100.000
Construction expenditures in specific facilities	-	-	-	630,000	618,000	12,000	-	630,000
Total construction expenditures	1,399,100	5,470,300	137,900	5,823,700	2,993,800	2,829,900	69,000	12,900,000
Use	1,399,000	5,470,000	138,000	5,824,000	2,994,000	2,830,000	69,000	12,900,000

Cost allocation - #9 Irondale Reservoir
allocation by separable costs - remaining benefits method

Project purposes	Flood control	Water quality	Water supply	Total recreation	General recreation	Total fish & wildlife	Navigation	Total
Allocation of annual charges								
Benefits	63,400	320,000	7,600	448,500	243,600	204,900	4,000	843,500
Alternate costs	304,000	324,800	456,800	353,900	192,200	161,700	4,000	1,443,500
Benefits limited by alternate costs	63,400	320,000	7,600	353,900	192,200	161,700	4,000	748,900
Initial separable costs	45,300	-	-	62,900	62,500	400	-	108,200
Applicable benefits before dual costs	-	320,000	-	49,100	29,200	19,900	3,900	373,000
Allocated dual cost (water quality block storage)	-	36,300	-	5,600	3,300	2,300	400	42,300
Applicable benefits before dual costs	-	-	7,600	208,900	124,200	84,700	100	216,600
Allocated dual cost (water supply block storage)	-	-	5,000	137,000	81,500	55,500	100	142,160
Total separable cost	45,300	36,300	5,000	205,500	147,300	58,200	500	292,600
Remaining benefits	18,100	283,700	2,600	148,400	44,900	103,500	3,500	456,300
Allocated residual cost	12,100	189,900	1,700	99,400	30,100	69,300	2,300	305,400
Total allocation of project cost	57,400	226,200	6,700	304,900	177,400	127,500	2,800	598,000
Benefit-cost ratio (financial)	1.1	1.4	1.1	1.5	1.4	1.6	1.4	1.4
Allocation of operation and maintenance including supervision & administration costs								
Initial separable costs	6,000	-	-	34,000	34,000	-	-	40,000
Allocated dual costs (water quality block)	-	7,600	-	1,200	700	500	100	8,900
Allocated dual costs (water supply block)	-	-	1,400	38,300	22,800	15,500	-	39,700
Total separable cost	6,000	7,600	1,400	73,500	57,500	16,000	100	88,600
Allocated residual cost	1,600	25,100	200	13,200	4,000	9,200	300	40,400
Total allocation	7,600	32,700	1,600	86,700	61,500	25,200	400	129,000
Allocation of replacement costs								
Initial separable costs	1,000	-	-	7,000	7,000	-	-	8,000
Allocated dual costs (water quality block)	-	1,000	-	200	100	100	-	1,200
Allocated dual costs (water supply block)	-	-	300	7,100	4,200	2,900	-	7,400
Total separable cost	1,000	1,000	300	14,300	11,300	3,000	-	16,600
Allocated residual cost	100	2,100	-	1,200	400	800	-	3,400
Total allocation	1,100	3,100	300	15,500	11,700	3,800	-	20,000
Allocation of investment								
Annual investment	48,700	190,400	4,800	202,700	104,200	98,500	2,400	449,000
Allocated investment	1,486,600	5,812,200	146,500	6,187,700	3,180,900	3,006,800	73,300	13,706,300
Allocation of construction expenditures								
Specific investment	-	-	-	669,400	656,600	12,800	-	669,400
Investment in joint-use facilities	1,486,600	5,812,200	146,500	5,518,300	2,524,300	2,994,000	73,300	13,036,900
Interest during construction on joint-use facilities	87,500	341,900	8,600	324,600	148,500	176,100	4,300	766,900
Construction expenditures in joint-use facilities	1,399,100	5,470,300	137,900	5,193,700	2,375,800	2,817,900	69,000	12,270,000
Percent of construction expenditures on joint-use facilities	11.403	44.583	1.124	-	19.363	22.965	0.562	100.000
Construction expenditures in specific facilities	-	-	-	630,000	618,000	12,000	-	630,000
Total construction expenditures	1,399,100	5,470,300	137,900	5,823,700	2,993,800	2,829,900	69,000	12,900,000
Use	1,399,000	5,470,000	138,000	5,824,000	2,994,000	2,830,000	69,000	12,900,000

Cost Allocation Studies

Union Reservoir

Determination of Separable Costs

A. Total Separable Cost

1. Flood Control (Normal Pool Area = 6,500 acres = 100%)

a. Separable cost = $1,189,200 -$846,600 = $342,600

2. Water Quality

a. Separable cost = $1,189,200 -$1,025,400 = $163,800

b. But without water quality, the normal pool is reduced to 5,200 acres or $\frac{1,300}{6,500}$ = 20.0% and results in the following benefit loss: $1,835,800 -$1,463,900 = $371,900, of which $177,700 is water quality, $1,400 is navigation, $144,600 is general recreation and $48,200 is Fish and Wildlife. Total recreation = $192,800

c. Modified separable cost = $163,800 -(20.0% of $176,900 (annual specific cost of recreation) or $35,400) = $128,400

3. Water Supply

a. Separable cost = $1,189,200 -$985,500 = $203,700

b. But without water supply, the normal pool is reduced to 4,350 acres or $\frac{2,150}{6,500}$ = 33.1% and results in the following benefit loss: $1,835,800 -$1,344,200 = $491,600, of which $172,100 is water supply, $400 is navigation, $239,300 is general recreation and $79,800 is Fish and Wildlife. Total recreation = $319,100

c. Modified separable cost = $203,700 -(33.1% of $176,900 (annual specific cost of recreation) or $58,600) = $145,100

B. Operation and Maintenance (including supervision and administration costs)

1. Flood Control

a. Separable cost = \$204,000 -\$175,000 = \$29,000

2. Water Quality

a. Separable cost = \$204,000 -\$174,000 = \$30,000

b. Modified separable cost = \$30,000 -(20.0% of \$103,100) = \$9,400

3. Water Supply

a. Separable cost = \$204,000 -\$157,000 = \$47,000

b. Modified separable cost = \$47,000 -(33.1% of \$103,100) = \$12,900

C. Replacement Costs

1. Flood Control

a. Separable cost = \$28,000 -\$20,000 = \$8,000

2. Water Quality

a. Separable cost = \$28,000 -\$23,000 = \$5,000

b. Modified separable cost = \$5,000 -(20.0% of \$13,000) = \$2,400

3. Water Supply

a. Separable cost = \$28,000 -\$21,000 = \$7,000

b. Modified separable cost = \$7,000 -(33.1% of \$13,000) = \$2,700

Cost allocation - P?? Union Reservoir
Summary of construction expenditures, annual financial charges and benefits (dollars)

	Multiple-purpose project: Specific costs: Cultural mitigation	Fish & wildlife	Joint-use costs	Total costs	Alternate single-purpose projects: Flood control	Water quality	Water supply	Recreation	Alternate multiple-purpose projects: Flood control, water quality, recreation, and navigation	Flood control, water supply, recreation, and navigation	Water quality, water supply, recreation, and navigation	Flood control, water supply, water supply, and navigation
01. Lands and damages	720,000	-	6,300,000	7,020,000	3,000,000	1,275,000	1,300,000		3,877,000	4,110,000	2,355,000	6,300,000
02. Relocations	-	-	3,372,000	3,372,000	3,[illegible]	1,[illegible]	1,822,000		3,417,000	3,406,000	3,467,000	3,393,000
03. Reservoirs	-	-	986,000	986,000	986,000	640,000	672,000		982,000	984,000	724,000	933,000
04. Dams	-	-	11,937,000	11,937,000	11,140,000	9,[illegible]	10,[illegible]		11,379,000	11,321,000	10,236,000	12,005,000
06. Fish & wildlife facilities	-	13,000	-	13,000	-	13,000	13,000		13,000	13,000	13,000	13,000
08. Roads, railroads & bridges	-	-	436,000	436,000	432,000	441,000	437,000		432,000	433,000	435,000	434,000
14. Recreational facilities	1,000,000	-	-	1,0[illegible]	-	-	-		720,000	871,000	1,004,000	-
19. Buildings, grounds & utilities	-	-	276,000	276,000	60,000	63,000	62,000		264,000	280,000	262,000	276,000
20. Permanent operating equipment	-	-	224,000	224,000	93,000	90,000	94,000		193,000	196,000	194,000	224,000
Total for project	1,740,000	13,000	25,730,000	27,300,000	20,000,000	14,200,000	14,600,000	19,000,000	23,200,000	23,000,000	19,000,000	25,000,000
Investment												
Construction period (years)				4	4	3	3	3	4	4	3	4
Interest during construction	180,300	800	1,000,700	1,718,000	1,300,000	665,600	606,400	890,600	1,430,000	1,407,300	890,600	1,612,300
Total investment	1,857,300	13,800	27,347,700	29,218,000	22,100,000	14,865,600	13,286,400	19,890,600	24,630,000	23,207,300	19,890,600	27,412,300
Annual charges												
Interest & amortization	60,000	300	893,900	957,200	726,000	487,000	380,700	651,000	807,300	888,400	651,600	890,000
Operation & maintenance	95,000	-	93,000	188,000	77,000	38,000	39,000	133,000	145,000	166,000	162,000	93,000
Operation & administration	7,300	-	7,900	15,000	7,000	6,000	6,000	10,000	12,000	13,000	13,000	8,000
Replacement costs	13,000	-	15,000	28,000	3,000	3,000	3,000	10,000	21,000	23,000	20,000	13,000
Total annual charges	175,300	300	1,011,800	1,189,300	813,000	534,000	368,700	812,000	985,300	1,085,400	846,000	1,014,000
Benefits												
Flood control				472,700					472,700	472,700	-	472,700
Water quality - local				21,900					21,900	-	21,900	21,900
- U-7				135,000					135,000	-	135,000	153,000
Water supply - U-7				172,100					-	172,100	172,100	172,100
General recreation				722,900					488,000	370,300	722,900	-
Fish & wildlife recreation				283,300					283,300	237,100	283,300	44,300
Navigation				5,100					4,700	3,700	5,100	3,100
Total annual benefits				1,8[illegible]					1,394,200	1,463,900	1,353,100	871,900

Cost allocation - [illegible] Union Reservoir
Allocation by separable costs - remaining benefits method

Project purpose	Flood control	Water quality	Water supply	Total recreation	General recreation	Total fish & wildlife	Navigation	Total
Allocation of annual charges								
Benefits	472,700	177,700	172,100	1,080,200	722,900	285,300	3,100	1,835,800
Alternate costs	813,000	354,000	368,700	812,600	-	-	3,100	-
Benefits limited by alternate costs	472,700	177,700	172,100	812,600	382,600	230,000	3,100	1,640,200
Related separable costs	342,600	-	-	177,400	176,900	300	-	520,000
Applicable benefits before dual costs	-	177,700	-	192,800	144,600	48,200	1,400	371,900
Allocated dual cost (water quality block storage)	-	61,400	-	66,300	49,900	16,600	300	128,400
Applicable benefits before dual costs	-	-	172,100	319,100	239,300	79,800	400	491,600
Allocated dual cost (water supply block storage)	-	-	50,800	94,200	70,600	23,600	100	145,100
Total separable cost	342,600	61,400	50,800	338,100	297,400	40,700	600	793,300
Remaining benefits	130,100	116,300	121,300	474,300	285,200	189,300	4,300	846,700
Allocated residual cost	60,800	54,300	56,700	221,800	133,300	88,300	2,100	393,700
Total allocation of project cost	403,400	115,700	107,500	559,900	430,700	129,200	2,700	1,189,200
Benefit-cost ratio (financial)	1.17	1.54	1.60	1.88	1.68	2.21	1.00	1.54
Allocation of operation and maintenance including supervision & administration costs								
Related separable costs	29,000	-	-	103,100	103,100	-	-	132,100
Allocated dual costs (water quality block)	-	4,500	-	4,900	3,700	1,200	-	9,400
Allocated dual costs (water supply block)	-	-	4,500	8,400	6,300	2,100	-	12,900
Total separable cost	29,000	4,500	4,500	116,400	113,100	3,300	-	154,400
Allocated residual cost	7,600	6,800	7,100	27,800	16,700	11,100	300	49,600
Total allocation	36,600	11,300	11,600	144,200	129,800	14,400	300	204,000
Allocation of replacement costs								
Related separable costs	8,000	-	-	13,000	13,000	-	-	21,000
Allocated dual costs (water quality block)	-	1,200	-	1,200	900	300	-	2,400
Allocated dual costs (water supply block)	-	-	1,000	1,700	1,300	400	-	2,700
Total separable cost	8,000	1,200	1,000	15,900	15,200	700	-	26,100
Allocated residual cost	300	300	300	1,000	600	400	-	1,900
Total allocation	8,300	1,500	1,300	16,900	15,800	1,100	-	28,000
Allocation of investment								
Annual investment	350,300	102,900	94,600	390,800	285,100	113,700	2,400	937,200
Allocated investment	10,943,300	3,141,000	2,887,700	12,173,500	8,702,800	3,470,700	73,300	29,218,800
Allocation of construction expenditures								
Specific investment	-	-	-	1,871,100	1,857,300	13,800	-	1,871,100
Investment in joint-use facilities	10,943,300	3,141,000	2,887,700	10,302,400	6,865,500	3,436,900	73,300	27,347,700
Interest during construction on joint-use facilities	643,700	184,800	169,900	606,000	402,700	203,300	4,300	1,608,700
Construction expenditures in joint-use facilities	10,299,600	2,956,200	2,717,800	9,696,400	6,442,800	3,253,600	69,000	25,739,000
Percent of construction expenditures on joint-use facilities	40.0134	11.4834	10.5592	37.6718	25.0313	12.6405	0.2680	100.0000
Construction expenditures in specific facilities	-	-	-	1,761,000	1,748,000	13,000	-	1,761,000
Total construction expenditures	10,299,600	2,956,200	2,717,800	11,457,400	8,190,800	3,266,600	69,000	27,500,000
Use	10,300,000	2,956,000	2,718,000	11,457,000	8,191,000	3,266,000	69,000	27,500,000

<u>Cost Allocation Studies</u>

Pine Ford Reservoir

Determination of Separable Costs

A. Total Separable Cost

1. Flood Control (Normal Pool Area = 3,700 acres = 100%)

a. Separable cost = \$1,171,900 -\$750,400 = \$421,500

2. Water Quality

a. Separable cost = \$1,171,900 -\$976,200 = \$195,700

b. But without water quality, the normal pool is reduced to 3,100 acres or $\frac{600}{3,700}$ = 16.2% and results in the following benefit loss: \$1,840,200 -\$1,590,600 = \$249,600, of which \$74,200 is water quality, \$1,600 is navigation, \$142,000 is general recreation and \$31,800 is Fish and Wildlife. Total recreation = \$173,800

c. Modified separable cost = \$195,700 -(16.2% of \$211,000 (annual specific cost of recreation) or \$34,200) = \$161,500

3. Water Supply

a. Separable cost = \$1,171,900 -\$946,800 = \$225,100

b. But without water supply, the normal pool is reduced to 2,800 acres or $\frac{900}{3,700}$ = 24.3% and results in the following benefit loss: \$1,840,200 -\$1,498,000 = \$342,200, of which \$81,400 is water supply, \$213,000 is general recreation and \$47,800 is Fish and Wildlife. Total recreation = \$260,800

c. Modified separable cost = \$225,100 -(24.3% of \$211,000 (annual specific cost of recreation) or \$51,300) = \$173,800

B. Operation and Maintenance (including supervision and administration costs)

1. Flood Control

a. Separable cost = $223,000 -$192,000 = $31,000

2. Water Quality

a. Separable cost = $223,000 -$187,000 = $36,000

b. Modified separable cost = $36,000 -(16.2% of $125,400) = $15,700

3. Water Supply

a. Separable cost = $223,000 -$176,000 = $47,000

b. Modified separable cost = $47,000 -(24.3% of $125,400) = $16,500

C. Replacement Costs

1. Flood Control

a. Separable cost = $30,000 -$20,000 = $10,000

2. Water Quality

a. Separable cost = $30,000 -$20,000 = $10,000

b. Modified separable cost = $10,000 -(16.2% of $15,400) = $7,500

3. Water Supply

a. Separable cost = $30,000 -$19,000 = $11,000

b. Modified separable cost = $11,000 -(24.3% of $15,400) = $7,300

Cost allocation - #2A Pine Ford Reservoir
Summary of construction expenditures, annual financial charges and benefits (dollars)

	Multiple-purpose project: Specific costs: General recreation	Multiple-purpose project: Specific costs: Fish & wildlife	Multiple-purpose project: Joint-use costs	Multiple-purpose project: Total costs	Alternate single-purpose project: Flood control	Alternate single-purpose project: Water quality	Alternate single-purpose project: Water supply	Alternate single-purpose project: Recreation	Alternate multiple-purpose projects: Flood control, water quality, recreation, and navigation	Alternate multiple-purpose projects: Flood control, water supply, recreation, and navigation	Alternate multiple-purpose projects: Water quality, water supply, recreation, and navigation	Alternate multiple-purpose projects: Flood control, water supply, water quality and navigation
01. Lands and damages	870,000	-	5,900,000	6,770,000	2,605,000	1,201,000	1,337,000		3,725,000	3,871,000	2,460,000	5,900,000
02. Relocations	-	-	7,218,000	7,218,000	4,407,000	1,378,000	1,331,000		5,093,000	6,184,000	1,975,000	7,218,000
03. Reservoir	-	-	390,000	390,000	360,000	265,000	271,000		390,000	390,000	287,000	390,000
04. Dams	-	-	9,888,000	9,888,000	9,500,000	8,512,000	8,326,000		9,725,000	9,698,000	8,791,000	9,905,000
06. Fish & wildlife facilities	-	13,000	-	13,000	-	13,000	13,000		13,000	13,000	13,000	13,000
08. Roads, railroads & bridges	-	-	464,000	464,000	465,000	473,000	468,000		465,000	462,000	470,000	464,000
14. Recreational facilities	1,147,000	-	-	1,147,000	-	-	-		933,000	1,028,000	1,267,000	-
19. Buildings, grounds & utilities	-	-	277,000	277,000	61,000	62,000	61,000		262,000	260,000	262,000	277,000
20. Permanent operating equipment	-	-	225,000	225,000	94,000	96,000	95,000		194,000	194,000	195,000	225,000
Total for project	2,017,000	13,000	24,370,000	26,400,000	17,500,000	12,000,000	12,300,000	15,400,000	21,600,000	22,100,000	15,700,000	24,400,000
Investment												
Construction period (years)				4	3	3	3	3	4	4	3	4
Interest during construction	126,100	800	1,523,100	1,650,000	820,300	562,500	576,600	721,900	1,330,000	1,381,300	735,900	1,525,000
Total investment	2,143,100	13,800	25,893,100	28,050,000	18,320,300	12,562,500	12,876,600	16,121,900	22,930,000	23,481,300	16,435,900	25,925,000
Annual charges												
Interest & amortization	70,300	400	848,200	918,900	600,200	411,500	421,800	528,200	751,800	769,200	538,400	849,300
Operation & maintenance	117,000	-	90,000	207,000	61,100	56,400	56,600	148,000	163,000	173,000	178,000	90,000
Supervision & administration	8,400	-	7,600	16,000	5,900	5,600	5,400	11,000	13,000	14,000	14,000	9,000
Replacement costs	15,400	-	14,600	30,000	3,000	2,000	2,000	17,000	19,000	20,000	20,000	14,000
Total annual charges	211,000	400	960,500	1,171,900	670,200	475,500	485,800	704,200	946,800	976,200	750,400	962,300
Benefits												
Flood control				377,700	377,700	-		-	377,700	377,700	-	377,700
Water quality - local				-	-	-		-	-	-	-	-
- R-7				74,200	-	74,200		-	74,200	-	74,200	74,200
Water supply - R-7				81,400	-	-		-	-	81,400	81,400	81,400
General recreation				876,500	-	-		876,500	663,500	736,500	876,500	-
Fish & wildlife recreation				228,800	-	-		228,800	181,000	197,000	228,800	32,200
Navigation				1,600	-	-		-	1,600	-	1,600	1,600
Total annual benefits				1,640,200	377,700	74,200		1,105,300	1,498,000	1,390,600	1,262,500	767,100

Incl 4

Cost allocation - F2A Pine Ford Reservoir
allocation by separable costs - remaining benefits method

Project purposes	Flood control	Water quality	Water supply	Total recreation	General recreation	Total fish & wildlife	Navigation	Total
Allocation of annual charges								
Benefits	577,700	74,200	81,400	1,105,300	876,500	228,800	1,600	1,840,200
Alternate costs	670,200	475,500	485,800	704,200	-	-	1,600	-
Benefits limited by alternate costs	577,700	74,200	81,400	704,200	558,400	145,800	1,600	1,439,100
Initial separable costs	421,500	-	-	211,400	211,000	400	-	632,900
Applicable benefits before dual costs	-	74,200	-	173,800	142,000	31,800	1,600	249,600
Allocated dual cost (water quality block storage)	-	40,000	-	112,500	91,900	20,600	1,000	161,500
Applicable benefits before dual costs	-	-	81,400	260,800	213,000	47,800	-	342,200
Allocated dual cost (water supply block storage)	-	-	41,300	132,300	108,200	24,300	-	173,800
Total separable cost	421,500	40,000	41,300	456,400	411,100	45,300	1,000	968,200
Remaining benefits	156,200	34,200	40,100	247,800	147,300	100,500	600	470,900
Allocated residual cost	67,600	11,300	17,300	107,200	63,700	43,500	300	203,700
Total allocation of project cost	489,100	51,300	58,600	563,600	474,800	88,800	1,300	1,171,900
Benefit-cost ratio (financial)	1.18	1.25	1.39	1.96	1.85	2.58	1.23	1.57
Allocation of operation and maintenance including supervision & administration costs								
Initial separable costs	31,000	-	-	125,400	125,400	-	-	156,400
Allocated dual costs (water quality block)	-	4,700	-	10,900	8,900	2,000	100	15,700
Allocated dual costs (water supply block)	-	-	3,900	12,600	10,300	2,300	-	16,500
Total separable cost	31,000	4,700	3,900	148,900	144,600	4,300	100	188,600
Allocated residual cost	11,400	1,900	2,900	18,100	10,800	7,300	100	34,400
Total allocation	42,400	6,600	6,800	167,000	155,400	11,600	200	223,000
Allocation of replacement costs								
Initial separable costs	5,900	-	-	15,400	15,400	-	-	21,300
Allocated dual costs (water quality block)	-	1,300	-	3,100	2,500	600	-	4,400
Allocated dual costs (water supply block)	-	-	1,000	3,300	2,700	600	-	4,300
Total separable cost	5,900	1,300	1,000	21,800	20,600	1,200	-	30,000
Allocated residual cost	-	-		-		-	-	-
Total allocation	5,900	1,300	1,000	21,800	20,600	1,200	-	30,000
Allocation of investment								
Annual investment	440,800	51,400	50,800	374,800	298,800	76,000	1,100	918,900
Allocated investment	13,455,700	1,569,000	1,550,700	11,441,000	9,121,100	2,319,900	33,600	28,050,000
Allocation of construction expenditures								
Specific investment	-	-	-	2,156,900	2,143,100	13,800	-	2,156,900
Investment in joint-use facilities	13,455,700	1,569,000	1,550,700	9,284,100	6,978,000	2,306,100	33,600	25,893,100
Interest during construction on joint-use facilities	791,500	92,300	91,200	546,100	410,500	135,600	2,000	1,523,100
Construction expenditures in joint-use facilities	12,664,200	1,476,700	1,459,500	8,738,000	6,567,500	2,170,500	31,600	24,370,000
Percent of construction expenditures on joint-use facilities	51.966	6.059	5.988	35.855	26.949	8.906	0.129	100.0000
Construction expenditures in specific facilities	-	-	-	2,030,000	2,017,000	13,000	-	2,030,000
Total construction expenditures	12,664,200	1,476,700	1,459,500	10,768,000	8,584,500	2,183,500	31,600	26,400,000
Use	12,664,000	1,477,000	1,459,000	10,768,000	8,585,000	2,183,000	32,000	26,400,000

Cost Allocation Studies

Bourbeuse River Reservoir

Determination of Separable Costs

A. Total Separable Cost

1. Flood Control (Normal Pool Area = 850 acres = 100%)

   a. Separable cost = \$352,200 -\$278,600 = \$73,600

2. Water Quality

   a. Separable cost = \$352,200 -\$269,500 = \$82,700

   b. But without water quality, the normal pool is reduced to 450 acres or $\frac{400}{850}$ = 47.1% and results in the following benefit loss: \$478,900 -\$196,700 = \$282,200, of which \$175,700 is water quality, \$200 is navigation, \$88,900 is general recreation and \$17,400 is Fish and Wildlife. Total recreation = \$106,300

   c. Modified separable cost = \$82,700 -(47.1% of \$60,900 (annual specific cost of recreation) or \$28,700) = \$54,000

B. Operation and Maintenance (including supervision and administration costs)

1. Flood Control

   a. Separable cost = \$119,000 -\$98,000 = \$21,000

2. Water Quality

   a. Separable cost = \$119,000 -\$79,000 = \$40,000

   b. Modified separable cost = \$40,000 -(47.1% of \$34,900) = \$23,600

C. Replacement Costs

1. Flood Control

a. Separable cost = \$18,000 -\$12,000 = \$6,000 x 0.71839* = \$4,300

2. Water Quality

a. Separable cost = \$18,000 -\$4,000 = \$14,000

b. Modified separable cost = \$14,000 -(47.1% of \$5,500) = \$11,400 x 0.71839* = \$8,200

* Adjustment factor

Cost allocation - I-39 Bourbeuse River
Summary of construction expenditures, annual financial charges and benefits (dollars)

	Single-purpose project: Separable costs: General recreation	Fish & wildlife	Joint-use costs	Total costs	Alternate single-purpose projects: Flood control	Water quality	Water supply	Recreation	Alternate multiple-purpose projects: Flood control, water quality, recreation, and navigation	Flood control, water supply, recreation, and navigation	Water quality, water supply, recreation and navigation	Flood control water supply, water supply, and navigation
01. Lands and damages	180,000	-	640,000	820,000	370,000	136,000				443,000	243,000	640,000
02. Relocations	-	-	300,000	300,000	375,000	211,000				370,000	213,000	300,000
03. Reservoirs	-	-	127,000	127,000	120,000	105,000				125,000	106,000	127,000
04. Dams	-	-	3,666,000	3,666,000	3,412,000	2,915,000				3,399,000	2,933,000	3,702,000
06. Fish & wildlife facilities	-	4,000	-	4,000	-	14,000				14,000	14,000	4,000
08. Roads, railroads & bridges	-	-	440,000	440,000	457,000	462,000				457,000	461,000	440,000
14. Recreational facilities	438,000	-	-	438,000	-	-				250,000	404,000	-
19. Buildings, grounds & utilities	-	-	263,000	263,000	79,000	62,000				261,000	261,000	263,000
20. Permanent operating equipment	-	-	218,000	218,000	107,000	64,000				163,000	165,000	218,000
Total for project	618,000	4,000	5,700,000	6,370,000	4,920,000	3,990,000		2,720,000		5,320,000	4,990,000	5,800,000
Investment												
Construction period (years)				2	2	2		2		2	2	2
Interest during construction	19,000	100	180,000	199,100	153,000	124,700		83,300		172,300	155,900	181,300
Total investment	640,000	4,100	5,940,000	6,560,100	5,073,000	4,114,700		2,803,300		5,492,300	5,145,900	5,981,300
Annual charges												
Interest & amortization	20,300	100	194,600	215,300	166,200	126,000		92,200		188,300	160,600	195,900
Operation & maintenance	32,000	-	77,000	109,000	50,000	40,000		55,000		72,000	90,000	77,000
Supervision & administration	2,900	-	7,100	10,000	5,000	3,000		3,000		7,000	8,000	8,000
Replacement costs	5,300	-	12,300	18,000	1,000	1,000		8,000		4,000	12,000	13,000
Total annual charges	60,500	100	291,300	352,300	222,200	180,000		160,200		289,300	270,600	293,900
Benefits												
Flood control				86,000	86,000	-		-		86,000	-	86,000
Water quality - local				175,700	-	175,700		-		-	175,700	175,700
- U-T				-	-	-		-		-	-	-
Water supply - U-T				-	-	-		-		-	-	-
General recreation				188,700	-	-		188,700		99,000	188,700	-
Fish & wildlife recreation				27,700	-	-		27,700		10,300	27,700	8,300
Navigation				200	-	-		-		-	200	200
Total annual benefits				478,300	86,000	175,700		216,400		195,700	392,300	270,700

Cost allocation - 1-30 Bourbeuse River
allocation by separable costs - remaining benefits method

Budget summary	Flood control	Water quality	Water supply	Total recreation	General recreation	Total fish & wildlife	Navigation	Total
Allocation of annual charges								
Benefits	86,400	175,700	N/A	216,400	188,700	27,700	200	478,700
Alternate costs	222,200	180,800		160,200	-	-	200	-
Benefits limited by alternate costs	86,400	175,700		160,200	139,700	20,500	200	422,700
Separable costs	73,600	-		61,000	60,900	100	-	134,600
Applicable benefits before dual costs	-	175,700		106,300	88,900	17,400	200	282,200
Allocated dual cost (water quality block storage)	-	33,600		20,300	17,000	3,300	100	54,000
Applicable benefits before dual costs	-	-		-	-	-	-	-
Allocated dual cost (water supply block storage)	-	-		-	-	-	-	-
Total separable cost	73,600	33,600		81,300	77,900	3,400	100	188,600
Remaining benefits	13,800	142,100		78,900	61,800	17,100	100	234,100
Allocated residual cost	9,100	99,300		55,100	43,200	11,900	100	163,600
Total allocation of project cost	82,700	132,900		136,400	121,100	15,300	200	352,200
Benefit-cost ratio (financial)	1.05	1.32		1.39	1.56	1.81	1.00	1.36
Allocation of operation and maintenance including supervision & administration costs								
Initial separable costs	21,000	-		34,900	34,900	-	-	55,900
Allocated dual costs (water quality block)	-	7,100		4,300	3,600	700	-	11,400
Allocated dual costs (water supply block)	-	-		-	-	-	-	-
Total separable cost	21,000	7,100		39,200	38,500	700	-	67,300
Allocated residual cost	2,900	31,400		17,400	13,600	3,800	-	51,700
Total allocation	23,900	38,500		56,600	52,100	4,500	-	119,000
Allocation of replacement costs								
Initial separable costs	4,300	-		5,500	5,500	-	-	9,800
Allocated dual costs (water quality block)	-	5,100		3,100	2,600	500	-	8,200
Allocated dual costs (water supply block)	-	-		-	-	-	-	-
Total separable cost	4,300	5,100		8,600	8,100	500	-	18,000
Allocated residual cost	-	-		-	-	-	-	-
Total allocation	4,300	5,100		8,600	8,100	500	-	18,000
Allocation of investment								
Annual investment	54,500	89,300		71,200	60,900	10,300	200	215,200
Allocated investment	1,663,700	2,725,900		2,173,400	1,859,000	314,400	6,100	6,569,100
Allocation of construction expenditures								
Specific investment	-	-		629,100	625,000	4,100	-	629,100
Investment in joint-use facilities	1,663,700	2,725,900		1,544,300	1,234,000	310,300	6,100	5,940,000
Interest during construction on joint-use facilities	50,400	82,600		46,800	37,400	9,400	200	180,000
Construction expenditures in joint-use facilities	1,613,300	2,643,300		1,497,500	1,196,600	300,900	5,900	5,760,000
Percent of construction expenditures on joint-use facilities	28.0004	45.8905		25.9983	20.7764	5.2239	0.1026	100.0000
Construction expenditures in specific facilitie	-	-		610,000	606,000	4,000	-	610,000
Total construction expenditures	1,613,300	2,643,300		2,107,500	1,802,600	304,900	5,900	6,370,000
Use	1,613,000	2,643,000		2,108,000	1,803,000	305,000	6,000	6,370,000

Cost estimate
angler-use site
(boat access)

Federal		
.14 Recreation facilities		
Access road	$1,000	
Comfort station	6,500	
Subtotal		7,500
Contingencies		700
Total recreation facilities		8,200
.30 Engineering & design		1,000
.31 Supervision & administration		800
Total Federal cost		$10,000
Non-Federal		
.01 Lands	3,500	
.14 Recreation facilities		
Well w/pump	2,500	
Picnic tables	600	
Braziers	350	
Refuse containers	200	
Incinerator	350	
Subtotal		4,000
Contingencies		700
Total recreation facilities		4,700
Total lands and recreation facilities		8,200
.30 Engineering & design		1,000
.31 Supervision & administration		800
Total non-Federal cost		$10,000

Cost estimate
angler-use site
(road access)

Federal

.14 Recreation facilities

Boat launching ramp	$ 5,300	
Parking area, surface treatment	9,300	
Subtotal		14,600
Contingencies		1,400
Total recreation facilities		16,000

.30 Engineering & design	1,500
.31 Supervision & administration	1,000
Total Federal cost	$18,500

Non-Federal

.01 Lands	$ 3,500	
.14 Recreation facilities		
Well w/pump	2,500	
Comfort station	6,500	
Picnic tables	600	
Braziers	350	
Refuse containers	200	
Incinerator	350	
Road treatment	1,000	
Subtotal		11,500
Contingencies		1,500
Total recreation facilities		13,000
Total lands and recreation facilities		16,500
.30 Engineering & design		1,200
.31 Supervision & administration		800
Total non-Federal cost		$18,500

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
BOARD OF ENGINEERS FOR RIVERS AND HARBORS
WASHINGTON, D.C. 20315

IN REPLY REFER TO

ENGBR

10 August 1965

SUBJECT: Meramec River, Missouri, Summary Report

THRU: Chief of Engineers
ATTN: ENGCW-PD
Department of the Army

TO: Division Engineer
U. S. Army Engineer Division, Lower Mississippi Valley
Vicksburg, Mississippi

1. Reference is made to BERH letter of 27 July 1965 on the subject report. Further review has indicated the need for additional information as discussed in the following paragraphs.

2. The Board staff has recently been advised informally by a representative of HEW, Washington, that the report prepared by the Kansas City, Missouri office of HEW, dated December 1964, and included on Summary Report, as Attachment 1, is recognized as HEW's "official report." Attachment 2 of the Corps Summary Report, indicates that data furnished by HEW were translated by the Corps into storage requirements prior to project formulation. It is stated that back-up data are on file in the St. Louis District office. Accordingly, it is requested that sufficient information be furnished for the Board to determine the method used in conversion of HEW's values to those given by the Corps in Attachment 2. For example, in HEW's report Table No. VIII-5, it is indicated that the supplemental flow above a base flow which would be required in connection with water quality control in reach M-7 during September in the year 2070, is estimated at 939 m.g.d. or 1,460 c.f.s. Attachment 2, Table 6 (Corps report) shows the water quality requirement for the same period (summer season), to be 1,880 c.f.s. or 420 c.f.s. greater. For the month of September in the year 2020, the HEW report gives a value equivalent to 216 c.f.s. as compared to 572.4 c.f.s. shown by the Corps Attachment 2. It is requested that the reasons

AIR MAIL

and methods for these differences be clearly explained. Does HEW approve of the Corps changes in the method?

3. Attachment 5, Table 7, indicates that the value of reservoir storage allocated to evaporation increases rapidly in the later years of each reservoir project life. It is understood that the conservation pool elevation will generally stay the same throughout the project life of any one structure. It is not clear why the evaporation rate is less for the recreation use than for water supply and water quality control uses. Also, evaporation storage is less for 2020 needs than for 2045 needs as shown on Attachment 5, Table 8.

4. The Meramec Park project as proposed includes about 400,000 acre-feet of conservation storage including evaporation. Attachment 5, Table 8, indicates that if this project were constructed the water quality and water supply needs in sub-basin M-7 could be served adequately until after 2045. Based on current costs and unit benefit values, what would be the average annual benefits and benefit-cost ratios for each of the other projects if Union, Pine Ford, Irondale, and I-38 as proposed in the report were deferred for construction until the year 2020, assuming water supply and water quality storages for reach M-7 were maximized in the Meramec Park project first, and that needs for all purposes in the study remained constant after 2070.

5. Benefits for project purposes have been evaluated in many cases by using the least costly alternative single- or multiple-purpose reservoir which would most likely be constructed in the absence of the proposed project. The Secretary of Army's office has requested for similar reports that some development of alternatives for major structures be included in the report. It is suggested that specific cost data on the major alternatives used in deriving benefit values in the report be furnished for the information of the Board.

6. Benefits for water supply and water quality control are shown in Attachment 5, Table 9, as the summation of benefits for the local areas and for reach M-7. It is requested that information be furnished showing the breakdown between the local areas and reach M-7, for items of annual costs and annual benefits for the water supply and the water quality control features as they apply to each reservoir project recommended.

ENGBR 10 August 1965
SUBJECT: Meramec River, Missouri, Summary Report

7. There is inclosed a table showing allocated costs per acre-foot of storage for the primary purposes at each reservoir. Comments on the wide range in unit costs are invited.

8. It is not apparent from the summary report if consideration has been given to stage construction of reservoirs particularly with regard to the water quality and water supply storage requirements. Discussion of the value of stage construction would be appreciated.

9. Because of the heavy work load in ENGCW-PD, Planning and Reports at this time the Board staff has been delayed in discussing with that office certain policy matters which have developed in connection with the review of the report. It is anticipated that these matters will be discussed at an early date after which we will communicate further with your office.

10. Comments and revised pages, as appropriate, resulting from consideration of the foregoing would be appreciated at the earliest practicable date.

FOR THE BOARD:

Edmund H Lang

1 Incl
as

EDMUND H. LANG
Colonel, Corps of Engineers
Resident Member

Copy furnished: (w/incl)
Dist Engr, St. Louis
Div Engr, LMVD (for advance information)

COMMENTS

ON

BERH LETTER, 10 AUGUST 1965

SUBJECT: MERAMEC RIVER, MISSOURI, SUMMARY REPORT

References below refer to paragraphs in subject letter.

a. Reference paragraph 2 - water quality Reach M-7. The Department of Health, Education, and Welfare report, Table VIII-5, shows the maximum reservoir release required over and above a computed theoretical unregulated stream flow (Q_i) to meet the needs for water quality in Reach M-7. These values are based on the Rainwater method of analysis, which involves the use of several formulas. First, the total stream flow (Q_t) required to provide the acceptable level of quality control is determined. The value of Q_t is given for seasonal periods and is based on the assumption that primary and secondary treatment is provided. Consideration is then given to the return flow (Q_r), which represents a portion of the municipal and industrial water returned to the stream at selected load centers. In the case of the Meramec Basin, this is a subtractive quantity since the source of the return flow comes from underground water and is independent of the stream flow. The required stream flow, as modified by return flow (Q_r), is then determined by the formula $Q_o = Q_t - Q_r$. The Public Health Service then determined the amount of supplemental storage release ($_s$) by use of the formula $Q_o - Q_i = \;_s$, where Q_o equals stream flow demands in terms of c. f. s.; Q_i a computed statistical flow in terms of c. f. s., characterizing the present unregulated stream flow at each load center; and $_s$ being the difference in terms of c. f. s. between Q_o and Q_i. The 939 m. g. d., which is $_s$, shown for the month of September for the year 2070 in the Public Health Service report represents the reservoir release required for water quality in Reach M-7. By summating the monthly releases shown for 2070, the Public Health Service estimated the draft-on-storage required per year at 342,000 acre-feet. The 1,880 c. f. s. shown in Table 6, Attachment 2, of the Summary Report is the same stream flow demand (Q_o) as used by the Public Health Service. This figure was then compared by the District to the mass curve or daily flows (Q_i) for the Eureka gage to determine the amount of storage required to meet the 2070 demands over the critical periods of record. As indicated in Table 7, Attachment 2, of the

Summary Report, storage requirement for water quality only is estimated at 393,725 acre-feet to meet the 2070 needs in the lower basin area. The principal difference between the two storage values lies in the fact that the Public Health Service value for Q_i is based on a constant theoretical median monthly flow during a climatic year, whereas the Corps used actual flows over the actual periods of record. When adjusted to reflect concurrent demands for both water supply and water quality control and based on the first-added, last-added method of apportionment, 703,621 acre-feet of storage would be required for water quality in Reach M-7, as shown in Table 7 of Attachment 2. The Public Health Service, in using the Rainwater method, analyzed the needs for water supply and water quality control individually over the same theoretical base flow, without consideration of concurrent demands. It should be noted that no demand values are shown in the Public Health Service report; only the supplemental release ($_s$) is given. Values used by the Corps were obtained from the regional office of the Public Health Service. The Public Health Service is in complete agreement that its values of draft-on-storage, as shown in its report, do not reflect the amount of storage required to meet current demands for both water supply and quality control. It is also in full agreement that final determination of the amount of storage to be recommended is the responsibility of the Corps.

b. Reference paragraph 3 - storage allocated to evaporation. Table 7, Attachment 5, of the Summary Report shows allocations of storage to the various purposes. Evaporation requirements, as listed, apply only to downstream low-flow augmentation. Evaporation requirements for recreation are not listed separately, but are included in the total storage for that purpose. Generally speaking, as low-flow augmentation increases on a time phase basis, evaporation requirements increase in relation to demand and time. An exception is the evaporation requirements for the year 2045, which are slightly less than the requirements for the year 2020 in those reservoirs augmenting Reach M-7 flows. While the demands for the year 2045 are greater and the critical period longer than for the year 2020 demands, the net effect of evaporation and rainfall is less than for 2020. The reason for this difference lies in the fact that the critical period for the year 2045 demands includes more early spring and late fall and winter months than the 2020 demands, resulting in lesser evaporation requirements.

c. Reference paragraph 4 - deferring construction of Union, Pine Ford, Irondale, and I-38 Reservoirs. A reanalysis was made assuming Meramec Park Reservoir constructed initially, with the remaining four reservoirs deferred until the year 2020. Meramec Park would be capable of serving adequately the water quality needs in Reach M-7 to the year 2045, and water supply needs until sometime thereafter. Average annual benefits for Meramec Park Reservoir are estimated at $4, 333, 400, and average annual economic charges at $2, 074, 200, with a benefit-cost ratio of 2 to 1. Benefits applicable to the remaining reservoirs, Union, Pine Ford, Irondale, and I-38, were reevaluated assuming construction and operation as of the year 2020. Benefits applicable to increments of water supply storage were based on a single-purpose reservoir other than Meramec Park as the least costly alternative and discounted to the base year, 2020. Water quality needs in the upper basin area were also revised to reflect change in initial needs and discounting factors. The benefit-cost ratios for the five reservoirs, based on the above analysis, are compared with the benefit-cost ratios contained in the Summary Report, as shown in the following tabulation:

Reservoir	Summary Report	Reevaluation
Meramec Park	1.9	2.1
Pine Ford	1.4	1.4
Irondale	1.4	1.5
Union	1.4	1.2
I-38	1.3	1.3

While Meramec Park, acting alone, can fulfill the needs in the lower basin area for water quality to the year 2045 and water supply for sometime thereafter, the reservoir would not provide needed flood reductions and water quality control in the upper basin area and only partial flood reductions in the lower basin area, and only a portion of the urgent demand for waterborne recreation would be satisfied. Deferring construction of Union, Pine Ford, Irondale, and I-38 Reservoirs would result in benefits foregone amounting to approximately $4, 500, 000 annually, of which $3, 200, 000 would be in the lower basin area and $1, 300, 000 in the upper basin area. Details of this reanalysis are contained in inclosure 1.

d. Reference paragraph 5 - benefits based on least costly alternative. The costs of the most economical alternative means which would most likely be constructed in the absence of the proposed projects were used as a measure of benefits for water supply and water quality control. The value of benefits for water supply and water quality control was based on the cost of single-purpose reservoirs having sufficient storage capacity to meet the desired flow requirements for the purposes served. Meramec Park Reservoir site was used for the location of the single-purpose reservoirs since its unit cost per acre-foot of storage was found to be the least of all sites studied. Based on demands, construction increments of 25 years were used. These costs were then converted to an equivalent uniform annual value over a 100-year period of analysis and discounted to reflect the time differentials between the time of need and the base year. Specific cost data on these alternatives used in deriving benefit values are shown in inclosure 2.

e. Reference paragraph 6 - water supply and water quality control for local areas and Reach M-7. Information showing the breakdown by local areas (upper basin) and Reach M-7 (lower basin) for items of annual cost and annual benefits for water supply and water quality is contained in inclosure 3 for the reservoirs recommended. Only in Union Reservoir are there dual benefits that pertain to low-flow augmentation for water quality control. Releases for the lower basin also satisfy water quality requirements in local Reach B-4, located immediately downstream from the reservoir. Benefits applicable to the local reach are considered incidental. Meramec Park and Pine Ford Reservoirs both contain water quality for low-flow augmentation in the lower basin only. Reservoirs in the upper basin, Irondale and I-38, provide low-flow augmentation in the interest of water quality for the upper area only, and are not used for water quality augmentation in Reach M-7. Since water supply is required for only the lower basin, all costs and benefits applicable thereto in project formulation pertain only to the lower basin, Reach M-7.

f. Reference paragraph 7 - allocated costs per acre-foot of storage. The primary reasons for the wide range in allocated costs per acre-foot of storage were previously discussed in the inclosure to second indorsement, LMSED-B, 13 August 1965, to letter, ENGBR, Board of Engineers for Rivers and Harbors, 27 July 1965, subject:

Meramec River, Missouri, Summary Report. Essentially the differences in costs are due to the values based on the least costly alternatives from which the benefits are derived and discounting of values from the time that the needs are met. Particular reference is made to the value of $1.57 per acre-foot of water supply storage in Irondale Reservoir. Recreation carries the entire cost of this storage to sometime after the year 2045, when it is converted to use for water supply. The cost of this storage becomes approximately $72 an acre-foot when viewed in light of its dual purpose. Contract for the use of this storage for water supply would be based on a cost analysis at the time such storage is first used for that purpose. The amount of local participation for this reservoir is equivalent to approximately 23 percent of the total project cost, as compared to approximately 21 percent for Pine Ford and Union Reservoirs and 28 percent for Meramec Park Reservoir.

g. Reference paragraph 8 - stage construction. Consideration has been given to stage construction of reservoirs, with particular reference to the water quality and water supply storage requirements. In this determination, the initial stage was formulated to provide the maximum degree of flood control warranted; water quality to meet the needs to the year 2020 in the upper and lower basin areas; water supply to meet the needs in the lower basin to the year 2020; and recreation based on normal pool levels attainable through storage provided for water supply and water quality control. In the initial stage construction, consideration was given to appropriate design which would permit subsequent enlargement, with minimum modifications, to meet additional capacity requirements for the second 50-year period, and acquisition initially of all lands which would be needed to meet the ultimate project requirements. Second stage construction would require more costly relocations than if undertaken initially; extensive modification for spillway and appurtenant works; additional land acquisition to provide borrow area for embankment, since it is contemplated that embankment materials would be obtained from the reservoir area; and abandonment or removal of much of the recreational facilities constructed for the initial phase. While stage construction would result in reduced annual charges when discounted for the final 50 years, the total cost of the project would be substantially increased, and the benefits foregone, primarily for recreation, would more than offset these savings. Projects as formulated in the Summary Report are less costly when constructed

initially than when undertaken under stage construction. Furthermore, storage requirements to meet the second 50-year needs were found incrementally justified.

3 Incl
1. Pertinent data - deferred construction
2. Cost data - major alternatives
3. Pertinent data - water supply & water quality control

Economic Analysis Based on Deferred
Reservoir Construction

A. Meramec Park Reservoir alone (1970 construction)

Benefits	
1. Flood control	$ 827,600
2. Water quality (M-7 only)	618,500
3. Water supply (M-7 only)	
Base (thru 2045)	661,200
Increment (2045-2070)	7,300
Total water supply benefits	668,500
4. Total recreation including fish & wildlife	2,197,100
5. Navigation	21,700
Total gross benefits	4,333,400
Average annual economic charge	$2,074,200
Benefit-cost ratio	2.1 to 1

Incl 1

Economic Analysis Based on Deferred
Reservoir Construction

B. Deferred construction of Pine Ford, Irondale, Union and Bourbeuse River Reservoirs (2020 construction)

	#2A Pine Ford	#9 Irondale	#29 Union	I-38 Bourbeuse River
Benefits				
1. Flood control	$ 577,700	$ 63,400	$ 472,700	$ 86,600
2. Water quality				
Local	-	307,900	22,100	180,900
M-7	-	-	-	-
3. Water supply (M-7 only)	60,900	92,500	135,000	-
4. Total recreation	1,105,300	448,500	1,008,200	216,400
5. Navigation	-	-	100	-
Total gross benefits	1,743,900	912,300	1,638,100	483,900
Average annual economic charge	$1,283,800	$627,500	$1,311,600	$365,900
Benefit-cost ratio	1.4	1.5	1.2	1.3

Incl 2

Detailed Cost Data of Major Alternatives used for Benefit Evaluation

A. Low-flow augmentation water quality control
lower basin, Reach M-7

Line Item	1970 (1995 needs) Total storage @ 39,044 ac-ft Pool surface @ 3,200 acres	1995 (2020 needs) Total storage @ 108,814 ac-ft Pool surface @ 5,900 acres	2020 (2045 needs) Total storage @ 240,240 ac-ft Pool surface @ 9,600 acres	2045 (2070 needs) Total storage @ 858,081 ac-ft Pool surface @ 21,800 acres
1. Project first cost ($)				
01. Lands & damages	2,540,000 *	1,590,000	2,550,000	5,740,000
02. Relocations	1,320,000	1,340,000	3,434,000	7,082,000
03. Reservoir	636,000	790,000	947,000	1,255,000
04. Dam	8,506,000	9,130,000	9,816,000	11,291,000
06. Fish & wildlife facilities	11,000	11,000	11,000	11,000
08. Roads, railroads & bridges	175,000	175,000	175,000	175,000
19. Buildings, grounds & utilities	52,000	52,000	52,000	52,000
20. Permanent operating equipment	79,000	79,000	79,000	79,000
30. Engineering & design	1,314,000	1,370,000	1,582,000	2,074,000
31. Supervision & administration	847,000	900,000	1,127,000	1,541,000
Total project cost	15,400,000	15,437,000	19,773,000	29,300,000
Use	15,500,000	15,400,000	19,800,000	29,300,000
Increment of cost	15,500,000 *			
Increment of construction cost w/o future land easements	13,800,000	1,600,000	4,400,000	9,500,000
2. Project annual charges for operation and maintenance ($)				
a. Labor				
Resident Supt/Mechanic	9,000	9,000	9,000	11,000
Tractor-operator (@ $8,500/yr ea)	17,000	17,000	25,500	34,000
Laborer (@ $6,100/yr ea)	24,400	24,400	30,500	42,700
Total	50,400	50,400	65,000	87,700
Use	50,000	50,000	65,000	88,000
b. Maintenance (including supervision and administration costs)				
Seed, spray, etc.	800	1,200	-	-
Fuel	800	1,000	1,500	2,500
Maintenance of bldg, equip, etc.	1,000	2,000	2,500	4,000
Maintenance of roads, shoreline	3,200	5,900	9,600	21,800
Total	5,800	10,100	13,600	28,300
Use	6,000	10,000	14,000	28,000
c. Replacement costs	1,000	1,000	2,000	3,000
d. Total	57,000	61,000	81,000	119,000
e. Incremental operation & maintenance costs	57,000	4,000	20,000	38,000

* Reflects initial cost expenditures for securing options or interest in real estate sufficient to preclude development incompatible to the project on lands required for later staged development.

Detailed Cost Data of Major Alternatives used for Benefit Evaluation

B. Low-flow augmentation water supply lower basin, Reach M-7

Line Item	1970 (1995 needs) Total storage @ 36,544 ac-ft Pool surface @ 3,000 acres	1995 (2020 needs) Total storage @ 68,361 ac-ft Pool surface @ 4,000 acres	2020 (2045 needs) Total storage @ 108,417 ac-ft Pool surface @ 5,800 acres	2045 (2070 needs) Total storage @ 613,156 ac-ft Pool surface @ 12,600 acres
1. Project first cost ($)				
01. Lands & damages	1,652,000 *	1,077,000	1,528,000	3,368,000
02. Relocations	1,320,000	1,330,000	1,340,000	5,022,000
03. Reservoir	634,000	705,000	790,000	1,074,000
04. Dam	8,496,000	8,778,000	9,117,000	10,422,000
06. Fish & wildlife facilities	11,000	11,000	11,000	11,000
08. Roads, railroads & bridges	175,000	175,000	175,000	175,000
19. Buildings, grounds & utilities	52,000	52,000	52,000	52,000
20. Permanent operating equipment	79,000	79,000	79,000	79,000
30. Engineering & design	1,315,000	1,338,000	1,376,000	1,750,000
31. Supervision & administration	846,000	872,000	903,000	1,300,000
Total project cost	14,580,000	14,417,000	15,371,000	23,253,000
Use	14,600,000	14,400,000	15,400,000	23,300,000
Increment of cost	14,600,000 *			
Increment of construction cost w/o future land easements	13,800,000	600,000	1,000,000	7,900,000
2. Project annual charges for operation and maintenance ($)				
a. Labor				
Resident Supt/Mechanic	9,000	9,000	9,000	9,000
Tractor-operator (@ $8,500/yr ea)	17,000	17,000	17,000	25,500
Laborer (@ $6,100/yr ea)	24,400	24,400	24,400	30,500
Total	50,400	50,400	50,400	65,000
Use	50,000	50,000	50,000	65,000
b. Maintenance (including supervision and administration costs)				
Seed, spray, etc.	800	1,100	1,200	-
Fuel	800	900	1,000	2,000
Maintenance of bldg, equip, etc.	1,000	1,900	2,000	3,000
Maintenance of roads, shoreline	3,000	5,700	5,800	12,600
Total	5,600	9,600	10,000	17,600
Use	6,000	10,000	10,000	18,000
c. Replacement costs	1,000	1,000	1,000	2,000
d. Total	57,000	61,000	61,000	85,000
e. Incremental operation & maintenance costs	57,000	4,000	-	24,000

* Reflects initial cost expenditures for securing options or interest in real estate sufficient to preclude development incompatible to the project on lands required for later staged development.

Incl 3

Annual Benefits and Costs for Water Quality and Water Supply
(dollars)

Reservoir	Water quality		Water supply		Total
	Upper basin (local)	Lower basin (M-7)	Upper basin (local)	Lower basin (M-7)	
#2A Pine Ford					
Annual benefits	-	74,200	-	81,400	155,600
Annual costs (financial)	-	59,300	-	58,600	117,900
#9 Irondale					
Annual benefits	320,000	-	-	7,600	327,600
Annual costs (financial)	226,200	-	-	6,700	232,900
#17 Meramec Park					
Annual benefits	-	388,500	-	431,000	819,500
Annual costs (financial)	-	181,200	-	188,100	369,300
#29 Union					
Annual benefits	21,900	155,800	-	172,100	349,800
Annual costs (financial)	10,200	105,500	-	107,500	232,200
I-38 Bourbeuse River					
Annual benefits	175,700	-	-	-	175,700
Annual costs (financial)	132,900	-	-	-	132,900